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MODERN VIEWS OF PHYSICAL SCIENCE

BEING A

RECORD OF THE PROCEEDINGS OF THE CENTENARY MEETING

OF

THE FRANKLIN INSTITUTE

AT PHILADELPHIA

SEPTEMBER 17, 18 AND 19, 1924

BY

ELLWOOD HENDRICK, Sc.D.

PHILADELPHIA

THE FRANKLIN INSTITUTE

1925

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FOREWORD

THE following record of the Centenary Meeting of the Franklin Institute, with the little sketch of history that led to it, is prepared especially for lay members.

At the Centennial celebration the managers and officers endeavored to make fellow members and guests, who responded to the number of over seven hundred, both welcome and comfortable. In respect to expense it was wholly a subscription affair: not a cent of income or principal from endowment or research funds was used to defray costs.

As soon as the documents are all in hand the various addresses will be printed in full in three volumes, under the general headings of Physics, Chemistry and Engineering. A number are also appearing from time to time in the Journal of the Institute. But as many of these addresses were delivered more or less extemporaneously, or from notes only, there will naturally be some delay before the text in full can be made ready

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for the printer. Again, many of the papers are so replete with mathematical and other formulas that the lay reader will hardly sense their meaning and significance. Much of the language of science is unfortunately veiled to all but the initiate, and from Dr. Little's memorable paper on The Fifth Estate it will be gathered that their number is limited. Therefore the present little volume is designed to tell what the meeting was about rather than to form a complete record of it. Abstracts of the various papers are presented, which are long or short, not according to their relative importance but rather according to the incidence of the subject on familiar things and the ability of the chronicler to translate the text into the language of every-day life. Then, too, as three sessions were held simultaneously in different lecture rooms, many of these abstracts have had to be prepared from what some one present at a session could remember.

It is also premature to outline the ambitious plans of the Bartol Research Foundation, to which attention will be called in later numbers of the Journal of the Franklin Institute.

The principal effort has been to present as

much as possible of the substance of scientific revelation and speculation which was offered on this memorable occasion; to do this with the least possible use of scientific terminology, and with as little delay as the circumstances would allow.

FRANKLIN INSTITUTE

THE beginning of the Franklin Institute in 1824 was not heralded with trumpets and drums. It was born of the failure of a very resolute young man to get what he wanted, and of his subsequent meeting with another of like mind and temperament who desired to make his teaching practical. The name of the first was Samuel Vaughan Merrick, who was born in Hallowell, Maine, in 1801, came to Philadelphia while still in his teens, and there entered the counting-house of his uncle, Samuel Vaughan, a well-to-do wine merchant. He was diligent, competent and observing. Uncle Samuel had loaned a sum of money to a firm of mechanics who made fire-engines, but not profits, and were unable to pay back their debt. But Mr. Vaughan was a merchant, not a manufacturer, and when he secured judgment against the debtors and took over the property, he was no better off than before, for he could not find a purchaser disposed to enter the unpromising

business of making fire-engines. His nephew had just about reached his majority in an age of young men, when many captains of clipper ships were no more than 21 or 22 years old, and he accepted his uncle's offer to take over the establishment thus left on his hands, to see what he could do with it. Youth is glorious and unafraid,—in the exceptional man. So Samuel Merrick found himself, to use his own words, "the owner of a workshop, but without a mechanical education and with scarcely a mechanical idea!"

In Philadelphia, as in other leading cities of the country, there had been established a Mechanics Institute, and young Merrick asked his friend William Kneass, a copper-plate engraver, who later became engraver and die-sinker to the U. S. Mint, to propose him for membership. But here we must take account of the Personality of Cities which manifests itself in their respective institutions. Philadelphia has always had traditions of conservatism, and these permeated the administration of the Mechanics Institute. The young man from Maine was attempting to operate a broken-down fire-engine works in which skilled mechanics had

failed, and by his own confession he was not a mechanic at all. That he should have fortuitous possession of a machine-shop was in no sense, to the minds of the Committee on Admission, a qualification for membership, and he was blackballed.

Constitutions and by-laws and rules are often of great value as safeguards, but sometimes they inhibit progress. Young Merrick was not at the time a skilled mechanic and may have lacked some of the ostensible qualifications for membership. Nevertheless, within a few years he became one of the leading iron founders and producers of machinery in America.

To return to the Personality of Cities: the Mechanics Institute was observant of the more obvious of Philadelphia's traditions, but it missed the finer distinctions, the more subtle qualifications that spring from the higher reaches of the civic mind. There are questions about persons that one frequently hears among more eminent and potential citizens of great municipalities, and they are peculiar to each place. Thus in New York the common question about a new-comer is likely to be, What does he bring? While in Chicago it is the some-

what more abrupt, What has he got? In Boston it is asked, Where was he born? But in Philadelphia for centuries the more general enquiry has been, Who is he? The Mechanics Institute was probably willing if Samuel Merrick should become a mechanic first, that he might then more properly apply for membership. But original men are peculiar; they will not abide by the book. He was impatient to learn what he wanted to know, and unwilling to sign articles, and to fetch and carry beer and sandwiches according to the routine of apprentices. The Mechanics Institute did not ask and find out who Samuel Merrick really was, and so discover his merits. Thus great potentialities of usefulness and distinction were passed by. When Philadelphia later, after some hesitation it is true, found out who this young man really was, she chose him to be a Member of her Councils, and sent him to Europe to investigate illuminating gas. In return he aided in providing this great boon and convenience for the people of the city.

Merrick explained to his friend Kneass the lack in Philadelphia of such opportunity for study as he desired. It should be possible for

every man or boy to learn without hindrance, and at low cost, that which is known of the mechanic arts and also of science which underlies them. The road to progress, he held, can not endure artificial restrictions; it is opened only under great freedom of opportunity. Favor does not invite the best minds; opportunity does. And science, which is fundamental, is not to be acquired by the contacts and discussions of journeymen mechanics; it must be taught thoroughly and with understanding, so that those who might study according to his plan would be able to coordinate science with practice and practice with science. A school should be provided with just such opportunities, and this should be available by night as well as by day. Mechanical drawing should also be included in the course.

The more he thought of the notion the more ideas came to young Merrick. Inventions, he observed, are constantly being made by workers who are unable to reach the public, and it often occurs that important discoveries remain untried and unknown until they are made again in a later generation. This new Society should be able to call on honorable men, equipped with

the special knowledge that would fit them to examine inventions with understanding, and the Society should award a certificate of merit or other distinction to the originators of whatever they found deserving of it. This would provide an inventor with the necessary *cachet* to secure recognition.

Kneass was impressed with the merit of the plan, and he urged Merrick to put it into execution. Merrick was a man of action, already rescuing his fire-engine works from failure, and he hardly needed the stimulus, greatly as it must have pleased him. So he hired a hall, sent out a call for a meeting for the purpose of expounding his plan,—but nobody came in response to his invitation. Thinking that something must have gone amiss with his preparations he tried it again, but with the same result. Philadelphia was not interested. At least, at that time.

Of course Merrick had not yet learned the ways of his adopted city, and did not appreciate the fact that the city did not know of his adoption. It had not even troubled to enquire about him. There was no social *cartel* between the little town of Hallowell, Maine, and the great

city of Philadelphia. This trouble, however, William Kneass sensed, and he hit upon a solution. He had the advantage of being native born, and his, therefore, was to some extent the local viewpoint,—slightly myopic towards small towns in other States, but crystal clear in contemplating such an approved institution as the University of Pennsylvania. The great civic and social mind has never been beset with any doubt as to the standing of this fount of learning or in regard to the wise and scholarly men who comprise its Faculty. So William Kneass put Samuel Merrick into relation with the university by means of an introduction to one of its professors, Dr. William Hypolitus Keating.

Keating also was a young man, born at Wilmington, Delaware, in 1799. His ancestors had emigrated from Ireland to France in order to escape religious persecution, and the family had been ennobled by Louis XVI. His father, Baron John de Keating, was a colonel in the French army in the West Indies at the time of the outbreak of the Revolution, when he resigned and came to the United States, settling in Wilmington. His son William was graduated

from the University of Pennsylvania, later studied in France and Switzerland and then returned to his *alma mater* as Professor of Chemistry and Mineralogy. His meeting with Merrick was in 1823.

A mere introduction was sufficient to kindle the flame of enthusiasm between these two young men. To unite science with practice and practice with science was exactly what Keating wanted to do. And here was his opportunity, here his collaborator! So the two proceeded to conspire.

Their first step was to choose a group of men, for the most part young, all full of potentialities and well known in the community. Their aim was to get men of quality to support the enterprise. Here be it said that this feature of seeking the best quality in men and measures has remained a distinctive policy of the Institute during its entire century of life.

These were the men:

Matthias W. Baldwin, founder of the Baldwin Locomotive Works; born in New Jersey in 1795 and apprenticed at sixteen to a firm of jewelers. In 1819 he set up in business for himself and patented a process for gold plating

that later was universally adopted. He also made tools for calico printers and for bookbinders, and in 1822 he built a five horse-power steam engine.

Colonel Peter A. Browne, attorney at law. He delivered the address at the laying of the corner-stone of the Institute, placing in the cavity a bronze head of Washington. He joined with John Haviland and others in organizing the arcade on Chestnut Street near Seventh. He was put in charge of three hundred special constables to quell a serious riot between the whites and the blacks. He was active in the introduction of gas into Philadelphia, and he offered resolutions at a patriotic meeting in support of the President of the United States in regard to the war with Mexico. He was a citizen of importance.

Oran Colton.

Thomas Fletcher.

Robert E. Griffith, physician, botanist, conchologist, who died in 1850 in his fifty-third year. He taught in the Philadelphia College of Pharmacy, and later at the University of Virginia. A man of very wide interests who had a working concept of many branches of natural

and physical science. He published "Medical Botany" and the "Universal Formulary," and he gave his extensive collection of shells to the Philadelphia Academy of Natural Sciences, of which he was vice-president in 1849 and '50.

William H. Keating. See text. His early death was a great loss to science in America. He was sound in scientific scholarship, an intense enthusiast in the development of applied physical science, and a natural leader of men.

William Harkness.

David A. Mason.

Samuel Vaughan Merrick. See text.

James Ronaldson, a Scotchman. Born in 1770. Came to Philadelphia in 1791, and was probably the oldest of the fourteen selected by Merrick and Keating to launch the Franklin Institute, of which he became the first president. A successful type-founder and one of the leaders in the Philadelphia cotton textile industry. Also noted as a philanthropist.

James Rush, builder of steam-engines. Was active, along with Colonel Peter Browne, Samuel V. Merrick and others in introducing gas lighting into Philadelphia.

George Washington Smith, born in Philadel-

phia in 1800. Died in 1876. Was admitted to the bar in 1823, but did not practise. He was rich, liberal, and a man of marked general and scientific culture. Spent several years in Europe and Asia in archaeological research. A founder of the Pennsylvania Historical Society, and at the time of his death was its senior vice-president. He contributed $5000 a year to the Episcopal Hospital, was a member of the American Philosophical Society; published "Facts and Arguments in Favour of Adopting Railroads in Preference to Canals," and many other works. He was but twenty-four at the founding of the Institute.

M. T. Wickham.

Samuel R. Wood.

The majority of these men were young. So far as we can learn only two of them were rich. While many were known to Philadelphia society this did not hold true of them all. They were selected for their abilities and potentialities, in which respect the two young founders showed remarkable judgment.

The next step was to call a public meeting to launch the proposed Institute. To this end a careful selection of 1500 best-known names

was made from the city directory, and to these was sent an invitation signed by the fourteen promoters, to meet at the County Court House on Sixth and Chestnut Streets, on February 5, 1824.

"The meeting," wrote Samuel Merrick later, "was a perfect success, and the novel method of throwing open the association to the world without the intervention of cliques made it universally popular."

Note, please, a curious manifestation of democracy on the occasion. The Mechanics Institute was designed to aid worthy artisans to improve themselves in their respective crafts, and straightway it narrowed its portals after the manner of an ancient guild. Its tendency was to become a close corporation, to keep out those who were not on terms of amity with the management. This view we draw from Merrick's apparent belief that he was kept out by a "clique," and from the probability that apprentices were admitted after they had completed a proper time of service.

On the other hand we have this newer institute, organized and supported largely by men of wealth and social standing, which had for

its very foundation the utmost in democracy: that its doors and privileges and membership be open to every worthy person who wanted to join. Some day we may learn that democracy is not consistent with dictatorship by the proletariat. Democracy, like the truth, is a very subtle thing; it frequently disappears and is gone while yet we think we have it with us.

James Ronaldson presided at the meeting; Colonel Browne explained its purposes; others added their exposition to his, and when the plan was thoroughly understood it was unanimously approved. Then the projected constitution was presented, its provisions discussed and amended, and finally adopted, and a day for election of officers was set.

Between four and five hundred persons enrolled as members, and on March 3, 1824, the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts received its charter from the State Legislature.

More members joined. James Ronaldson was elected President. Samuel Merrick and William Keating were made members of the Board of Managers. Dr. Keating was made Professor of Chemistry, Robert M. Patterson

Professor of Natural Philosophy and Mechanics, and William Strickland Professor of Architecture.

The purpose of the Institute, as set forth, was to maintain courses of lectures on the mechanic arts and on applications of science, to maintain a library of books relating to science and the useful arts, all supplemented by a reading room. It was also to provide that inventions be examined and reported on by a committee of learned and honorable men; to publish a journal containing essays on science and the arts, specifications of British and American patents, etc., to hold exhibitions of American manufactures and to award medals to worthy inventors, to build a hall for meetings and for the uses of the Institute, to collect machines, minerals, and materials used in the mechanic arts, to establish schools to teach architecture, mechanical drawing, chemistry as applied to the arts, mechanics, and, if possible, to organize a high school for giving young men an education both liberal and practical.

There was at this time a publication called "The Mechanics' Magazine, Register, Journal & Gazette," issued in New York and edited by Dr.

Thomas P. Jones. Its purpose was to serve science as Littell's Living Age later served literature. The Institute bought this, changed its name to "The Franklin Journal and Mechanics' Magazine," and transferred the publishing to Philadelphia. Dr. Jones not only accepted the invitation to continue as editor, but also became Professor of Mechanics at the school of the Institute. Abstracts of patent specifications and claims in full were published in the Journal, a step not adopted by the U. S. Patent Office until 1843. Therefore the only available source for information in patent searches between 1826 and 1843 is to be found in the files of the Journal for these years. These are also used for reference in searches for all U. S. patents from 1826 to 1859. The publication of patents was discontinued as soon as the Official Gazette of the Government became adequate. Before long the name was changed to "The Journal of the Franklin Institute," and it has become one of the leading scientific periodicals.

The School was organized, and proceeded to hold sessions both by day and by night, early in the history of the movement. It provided a greatly needed opportunity for education—so

greatly needed that the Central High School of the city was later modeled on the same lines. This enabled the Institute to pass over its pupils to the Central High School and address itself to other work. The School of Mechanical Drawing, however, continued under its auspices for ninety-nine years and only stopped then because the Board of Education of the city incorporated like tuition in its system.

The lectures have continued regularly since the foundation, and a record of these constitutes a great compendium of the development and advances made in physical science and the mechanic arts during the century of amazing progress in which the Institute has made its history. They are held every week in the hall of the Institute, and have become a national affair. Beginning with the exposition of novel ideas in mechanics and the scientific history which underlies them, always stressing the reasons why, these weekly talks which begin in October and continue until some time in May have constantly aimed at the Peaks of Research as science has advanced. The Institute has become the meeting-place of the *cognoscenti,* of scholars in science from all over the world. The splendid

young men who, under the presidency of James Ronaldson, a hundred years ago organized and made the Franklin Institute have long since gone the way of all flesh. But they aimed high, and in this they have been competently followed by their successors throughout the generations.

To aim high is easy. Anyone may shoot an arrow at a star. But to aim high and to reach the heights in achievement calls for more qualities than ambition. It calls for scholarship, great energy, persistence, and the almost divine gift of avoiding fatal mistakes. These merits marked the founders and have distinguished their successors no less. Such men live in a world of rare understanding which the man on the street is hardly equipped to reach. They dwell and toil there for the great purpose of enlightening humanity.

A notable series of lectures, given in April, 1923, by Sir Joseph J. Thomson on the Electron in Chemistry will serve as an example. They were not designed for school-boys, for society belles, or for men who have ceased to think after the close of their school days. The whole series constitutes a record of what

thoughtful men regard as a true exposition of the nature of matter, that is at once prophetic of human thought, of philosophy and of religion,—if civilization is to endure.

A feature of great importance in the promotion of the mechanic arts has been the Institute's exhibitions, the first of which was held in Carpenters' Hall in the first year of its existence, and which were continued either annually or biennially in various places in Philadelphia until 1858. One of signal importance marked the fiftieth anniversary of the Institute, in 1874, being housed in the old freight station of the Pennsylvania Railroad Co. at Thirteenth and Market Streets. The last was in 1884, this time being devoted specifically to electricity, the first of its kind in the country, and it immediately assumed international importance. In later years the vast domain of science and the wide scope of the mechanic arts have become so diversified that displays which formerly were of great novelty would not be practicable now.

The Franklin Institute has never permitted its purposes to freeze, and in this it finds its perpetual youth and vigor. If the occasion should arise again to spread abroad information

and understanding within its great field of activity by means of an exhibition, we may be sure that this will be provided for. Perhaps some day it may be culturally profitable and timely to hold one devoted to the History of Science, which would be wholly within its province.

Another feature of the Institute, active for a century, is its Committee on Science and the Arts. This began as the Board of Examiners whose duty it was to investigate and report on all new and useful machines, inventions and discoveries submitted to it. It was changed in name to the Committee on Inventions, and in 1834 its scope was enlarged and it received its present designation. The work of this body is done without charge, and it has passed upon a large number of inventions, bringing those of usefulness to the light of day by its approval and awards, while saving many persons from disappointment and loss by the exposure of misconceptions, ignorance, fraud and false pretence. Many subjects come under its scrutiny, and it has served unofficially as scientific adviser to the city of Philadelphia for a hundred years. The Committee also determines who shall re-

ceive the medals, diplomas, and other recognitions of distinction conferred by the Institute.

The Gold Medal of the Franklin Institute is one of the leading prizes in the scientific world for achievement in research. It is given to those workers in physical science or technology whose efforts have done most to advance a knowledge of physical science or its applications, without regard to the country of origin or to nationality.

Other prizes are the Elliott Cresson Medal (gold) for discovery or research; the Howard N. Potts Medal (gold) for distinguished work in science or the arts; the Edward Longstreth Medal (silver) with a money premium when this has accumulated, for meritorious work in science or the arts. The Certificate of Merit is awarded to persons adjudged worthy thereof, for their inventions, discoveries or productions. The Boyden Premium of $1000 is waiting for anybody who shall determine whether all rays of light and other physical rays are or are not transmitted with the same velocity. In 1907 an award was made covering the solution of the problem so far as visible and ultra-violet rays are concerned. The balance is

retained to be awarded to the person who shall demonstrate whether infra-red rays are or are not transmitted with the same velocity as the others.

A record of the awards of these various prizes is no less than a comprehensive history of significant steps in the advancement of science. And so wise has the Committee been in its selections that, while naturally many leading contributors have not been included, remarkably few errors have been made.

The library was established in 1827, and it has grown and grown in scientific scope, in richness and in usefulness until it far exceeds the space available for its treasures. Open to the public, it is continually visited by those engaged in scientific and mechanical research.

Under the will of the late Henry W. Bartol the Institute received a bequest of approximately $2,000,000 to establish and maintain an institute of industrial research similar to the Mellon Institute of Industrial Research of the University of Pittsburgh. The land has been secured, but owing to the high cost of building the dwelling houses standing on it have been converted into temporary laboratories. It is

proposed to stress the subject of applied physics, while not forgetting chemistry and other branches of physical science. The charter is very broad, affording a practically unrestricted field for research,—which is as it should be. This is now in process of organization.

From the foregoing rapid glance at the record of the Franklin Institute in which membership with its privileges is open virtually to anybody who wants to join it, and in consideration of its great achievements in the cause of science and for the benefit of humanity, it has been considered fitting and proper that the one hundredth anniversary of its birth should be duly celebrated. As with the birth itself this was made neither an occasion for trumpets and drums nor for men on horseback, or pageantry and waving banners. It was rather a feast for the mind to which men of achievement came from far and near to give an account of their work. It was a busy time, a time of crowded sessions, and an historical event.

THE CELEBRATION

First a number of eminent men at home and abroad were invited to contribute papers. These are shown in the programme which follows:

WEDNESDAY, SEPTEMBER 17TH

9.00 A. M. Assembly of Delegates and Guests at the Hall of The Franklin Institute, 15 South Seventh Street.

9.45 A. M. Academic Procession from the Hall of The Franklin Institute to the Walnut Street Theater. (Academic Costume is in order but not required.)

10.15 A. M. Invocation.
The Reverend LOUIS C. WASHBURN, S.T.D., Rector of Christ Church, Philadelphia.

10.30 A. M. Address of Welcome.
The Honorable W. FREELAND KENDRICK, Mayor of Philadelphia.

Address:
President WM. C. L. EGLIN, Sc.D.

Address:
Professor ELIHU THOMSON, Ph.D., Sc.D., Honorary Chairman of the Centenary Celebration Committee of The Franklin Institute.

1.00 P. M. Luncheon to Delegates and Guests.
The Bellevue-Stratford.

2.30 P. M. Sectional Meetings.
The Franklin Institute, 15 South Seventh Street.
The University of Pennsylvania.

7.30 P. M. Dinner Parties.

THURSDAY, SEPTEMBER 18TH

10.00 A. M. Sectional Meetings.
The University of Pennsylvania.

1.30 P. M. Luncheon to Delegates and Guests.
The Bellevue-Stratford.

2.30 P. M. to 6.00 P. M. Garden Party.

8.30 P. M. Open Meeting.
The University Museum, 33rd and Spruce Streets.

President Wm. C. L. Eglin, Sc.D., presiding, will introduce the Chairman of the evening,

The Hon. WILLIAM CAMERON SPROUL, LL.D.

Address:

"The Natural and Artificial Disintegration of Elements,"

By Professor SIR ERNEST RUTHERFORD, Kt., D.Sc., LL.D., Ph.D., D.Phys., F.R.S., Trinity College, Cambridge, England.

FRIDAY, SEPTEMBER 19TH

9.30 A. M. Unveiling of Tablet at Bartol Research Foundation, 127 North 19th Street.
Mr. C. C. Tutwiler, presiding.

9.45 A. M. The Academy of Natural Sciences, 19th and Race Streets.

Address:

"The Fifth Estate,"

By ARTHUR D. LITTLE, Chem.D., Cambridge, Massachusetts.

Address:
"Stimulation of Research and Invention,"
By Professor D. S. JACOBUS, Dr.Eng., New York City.

11.30 A. M. Sectional Meetings.
The University of Pennsylvania.

2.00 P. M. Luncheon to Delegates and Guests.
The Bellevue-Stratford.

4.00 P. M. Convocation at The University of Pennsylvania.
President Josiah Harmer Penniman, Ph.D., LL.D., Litt.D., presiding.

7.30 P. M. Banquet to Delegates and Guests.
The Bellevue-Stratford.
Presentation of greetings from universities, colleges, learned and professional societies and industrial organizations.

SECTIONAL MEETINGS

WEDNESDAY, SEPTEMBER 17TH

2.30 P. M. The Hall of The Franklin Institute, 15 South Seventh Street.

Rear Admiral W. A. Moffett, presiding.

Addresses:

"Recent Developments in Aeronautics."

By Professor JOSEPH S. AMES, Ph.D., LL.D., The Johns Hopkins University.

"Military Aircraft and Their Use in Warfare,"

By Major General MASON M. PATRICK, Chief United States Air Service.

"Electrical Communications for Military Purposes,"

By Major General GEORGE OWEN SQUIER, Ph.D., United States War Department.

"Progress in Telephony,"

By General JOHN J. CARTY, D.Sc., LL.D., Vice-President American Telephone and Telegraph Company.

2.30 P. M. Lecture Room No. 216, Engineering Building, University of Pennsylvania.
Dean Howard McClenahan, presiding.

Addresses:

"Concentration and Polarization at the Cathode During Electrolysis of Solutions of Copper Salts,"

By Professor W. LASH MILLER, Ph.D., University of Toronto.

"The Theory of Color Production in Organic and Inorganic Compounds,"

By Professor JULIUS STIEGLITZ, Ph.D., D.Sc., Ch.D., University of Chicago.

"Photo-Elasticity,"

By Professor E. G. COKER, M.A., D.Sc., F.R.S., University College, London.

2.30 P. M. Lecture Room No. 226, Engineering Building, University of Pennsylvania.

Doctor Frank J. Sprague, presiding.

Addresses:

"The Progress and Promise of Engineering,"

By Dean DEXTER S. KIMBALL, M.E., The College of Engineering, Cornell University, Ithaca, New York.

"Some of the Effects of Loading Granular Material,"

By DANIEL E. MORAN, M.Sc., Consulting Engineer.

"Modern Military Engineering,"

By Brigadier General EDGAR JADWIN, United States War Department.

2.30 P. M. Lecture Room No. 314, Engineering Building, University of Pennsylvania.
Doctor Arthur L. Day, presiding.

Addresses:

"The Way of the Wind,"

By Professor W. J. HUMPHREYS, C.E., Ph.D., United States Weather Bureau.

"Modern X-ray Tube Development,"

By WILLIAM D. COOLIDGE, Ph.D., General Electric Company.

"Inorganic Crystals,"

By Professor WILLIAM LAWRENCE BRAGG, M.A., F.R.S., Victoria University, Manchester, England.

SECTIONAL MEETINGS

THURSDAY, SEPTEMBER 18TH

10.00 A. M. Harrison Chemical Laboratory, University of Pennsylvania. Doctor Willis R. Whitney, presiding.

Addresses:

"Technical Results of the Theoretical Development in Chemistry,"

By Professor F. HABER, Ph.D., Direktor des Instituts fuer Physikalische Chemie und Elektrochemie, Berlin.

"Electric Discharges in Gases at Low Pressures,"

By IRVING LANGMUIR, Ph.D., D.Sc., LL.D., General Electric Company.

"The Development of Colloid Chemistry,"

By Professor WILDER D. BANCROFT, Ph.D., Sc.D., Cornell University.

"Applied and Scientific Photography,"

By C. E. K. MEES, D.Sc., Director Eastman Kodak Company.

10.00 A. M. Lecture Room No. 214, Engineering Building, University of Pennsylvania.

General Guy E. Tripp, presiding.

Addresses:

"Some Aspects of High Pressure Research,"

By Professor P. W. BRIDGMAN, Ph.D., Harvard University.

"The Phonodeik,"

By Professor DAYTON C. MILLER, Sc.D., Case School of Applied Science.

"Electronic Phenomena at the Surface of Metals,"

By Professor CHARLES E. MENDENHALL, Ph.D., The University of Wisconsin.

"The Carbon Atom in Crystalline Structure,"

By Professor SIR WILLIAM HENRY BRAGG, K.B.E., M.A., D.Sc., F.R.S., Royal Institution of London.

10.00 A. M. Lecture Room No. 216, Engineering Building, University of Pennsylvania.

Professor Augustus Trowbridge, presiding.

Addresses:

"Some Causes of Volcanic Activity,"

By ARTHUR L. DAY, Ph.D., Sc.D., Director Geophysical Laboratory, Carnegie Institution.

"Spectroscopy in Past and Present,"

By Professor CHARLES FABRY, University of Paris.

"Infra-Red Spectroscopy,"

By Professor AUGUSTUS TROWBRIDGE, Ph.D., Princeton University.

"Lightning,"

By F. W. PEEK, General Electric Company.

"The Measurement of Acoustic Impedance by the Aid of the Telephone Receiver,"

By Professor A. E. KENNELLY, Sc.D., Harvard University and Massachusetts Institute of Technology.

10.00 A. M. University of Pennsylvania Museum.

Doctor Samuel Insull, presiding.

Addresses:

"The Field of Research in Industrial Institutions,"

By E. W. RICE, JR., Sc.D., D.Eng., Honorary Chairman, General Electric Company.

"Unusual Problems Encountered in the Design and Construction of Large Bridges,"

By RALPH MODJESKI, Dr.Engr., Consulting Engineer, Philadelphia.

"Steam Turbines on Land and Sea,"

By SIR CHARLES ALGERNON PARSONS, K.C.B., M.A., LL.D., D.Sc., F.R.S., Newcastle-on-Tyne.

"Mercury Boiler,"

By WILLIAM LEROY EMMET, Sc.D., General Electric Company.

SECTIONAL MEETINGS

FRIDAY, SEPTEMBER 19TH

11.30 A. M. Harrison Chemical Laboratory, University of Pennsylvania.
Professor Joseph S. Ames, presiding.

"The Origin of the Earth's Electric and Magnetic Phenomena,"

By Professor W. F. G. SWANN, D.Sc., Yale University.

Addresses:

"Radiating Atoms in Magnetic Fields,"

By Professor PIETER ZEEMAN, Ph.D., Sc.D., University of Amsterdam.

"Motion of Electrons in Gases,"

By Professor JOHN SEALY EDWARD TOWNSEND, F.R.S., University of Oxford, England.

"Electric Discharges Between High Resistance Electrodes,"

By J. SLEPIAN, M.A., Ph.D., The Westinghouse Electric and Manufacturing Company.

11.30 A. M. Lecture Room 226, Engineering Building, University of Pennsylvania.

Doctor Arthur D. Little, presiding.

Addresses:

"Twenty-Five Years' Progress in Explosives,"

By CHARLES L. REESE, Ph.D., Sc.D., Director E. I. du Pont de Nemours and Company.

"The Influence of J. Willard Gibbs on the Science of Physical Chemistry,"

By Professor F. G. DONNAN, C.B.E., M.A., Ph.D., D.Sc., F.I.C., F.R.S., University College, London.

"Early Science in Philadelphia,"

By Provost Emeritus EDGAR F. SMITH, Ph.D., LL.D., L.H.D., Chem.D., Litt.D., M.D., University of Pennsylvania.

11.30 A. M. Lecture Room 226, Engineering Building, University of Pennsylvania.

Professor A. E. Outerbridge, presiding.

Addresses:

"The Trend in Physical Metallurgy,"

By Professor C. H. MATHEWSON, Ph.D., Yale University.

"The Restraint of Exaggerated Grain Growth in Critically Strained Metals,"

By GEORGE L. KELLEY, Ph.D., Philadelphia.

"Magnetic Analysis of Steel,"

By Professor BRADLEY STOUGHTON, Lehigh University.

"Magnetic Properties of Fifty Per Cent Iron and Fifty Per Cent Nickel Alloys,"

By T. D. YENSON, E.E., The Westinghouse Electric and Manufacturing Co.

11.30 A. M. Lecture Room No. 314, Engineering Building, University of Pennsylvania.

Major General George O. Squier presiding.

Addresses:

"Results of a Preliminary Determination of the Velocity of Light,"

By Professor A. A. MICHELSON, Ph.D., Sc.D., LL.D., The University of Chicago.

"Modern Ordnance,"

By Major General C. C. WILLIAMS, United States War Department.

Invitations were sent to persons eminent in science the world over, who were bidden also to bring members of their families if they so desired. Acceptances to the number of 759 were received. Every arriving guest was met at the station by a representative of the Institute and escorted to the quarters assigned him in the dormitories of the University of Pennsylvania, the hospitality of which he was to enjoy. Once installed he received his budget of tickets for the various functions he had elected to attend: daily luncheon at the Bellevue-Stratford, a garden-party at the Philadelphia Country Club on Thursday afternoon, and the banquet on Friday night. Arrangements were made for guests to take breakfast and other unofficial meals at the Hotel Normandie. Besides the guests in the university dormitories, many were entertained at the houses of members, and others at hotels. These courtesies were also extended to out-of-town members. In all the group thus mustered, guests and members, numbered about seven hundred and fifty.

On Wednesday morning the party assembled in the ancient Hall of the Franklin Institute, a large number bringing their caps and gowns

and doctor's and master's hoods for the academic procession. But alas, it rained! It rained hard and fast for the only time during the celebration, so that some proceeded to the Walnut Street Theatre in automobiles and taxicabs, and others got over there as best they could, under the protection of raincoats and umbrellas; an academic procession in mufti! But they carried their canonicals with them, donning them in the theatre, so that parterre and stage soon were full of color. The sons and daughters of American universities were, of course, in black relieved only by their hoods, but the high alumni of British universities were gowned in red with doctors' caps that seemed to have come straight down from the XVI century, worn in place of mortar-boards. Still more striking figures were the doctors from the University of Paris in their scarlet and ermine.

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When the company was seated there appeared on the stage Dr. Eglin, President of the Institute, Mayor W. Freeland Kendrick of Philadelphia, Dr. Louis C. Washburn, Rector of Christ Church of Philadelphia—the church attended by Benjamin Franklin—Dr. Elihu Thom-

son of Lynn, and Acting Secretary Dr. George A. Hoadley. The meeting was opened by the minister, who prayed that we be delivered from irreligious science and unenlightened religion. It was the same divine who on another occasion urged that we learn to think more on our knees and to pray more on our feet. Mayor Kendrick told something of Philadelphia as a city where many celebrations are staged, bade all welcome, and then, at the call of pressing municipal duties, left the hall. Dr. Elihu Thomson, who has been a member of the Institute since 1874, was then introduced in his capacity as Honorary Chairman of the Centenary Committee.

As a boy Dr. Thomson attended the Central High School, which was developed from the school of the Institute, then he taught there, and at the age of twenty-three was giving lectures on electricity before the Institute. This was a venturesome undertaking; he had to make and set up his own apparatus, and his thesis was to demonstrate that electricity, whether static, galvanic or what not, is all one and the same thing under different modifications. The course lasted from 1874 to 1877, and during the last of the series he stumbled across his first

clue to electric welding. Dr. Thomson is credited with no fewer than 500 discoveries in the electrical field.

Outlining the history of the Institute, with emphasis on the broad scope of its activities, the speaker showed how it had always stood valiantly for progress in human understanding, with steady opposition to organized ignorance such as is shown in the propaganda of the anti-vivisectionists, anti-evolutionists, and the ever-noisy protestants against discovery. And side by side with this unwavering policy of enlightenment, as he said, it had brought the efforts of the two founders, Merrick and Keating, to combine a mechanics' body with a learned society, to a complete and impregnable success.

The activities of the Institute have been very closely bound up with the development of electricity and so Dr. Thomson was able to describe the various stratagems and devices of which the early workers in this field availed themselves to obtain results. A Chapter on Ingenuity, so this might be styled, in its splendid presentation of what these young pioneers accomplished with the scant means at their command. Com-

plaint is sometimes made that in our system of education students often grow stale before they finish their courses; that they are taught and taught and taught until they lose both curiosity and initiative. If young electrical engineers had heard this impromptu record of their predecessors' struggles it would have tended to encourage them to original thought while spurring their inventiveness.

Dr. Thomson dwelt on the advantage of the broad democracy which has always characterized the Institute by making it as easy as possible for those who want to improve their knowledge and efficiency to join it, with the resulting benefit to general enlightenment. The secrets of nature are not revealed as in a moving-picture show; it requires earnest preparation to understand what is already known, and thence to penetrate the unknown. Many who have the capacity to do this lack the opportunity, and it is such an opportunity that Merrick, Keating, and their fellow founders provided and their successors have maintained.

An invitation from the University of Pennsylvania to a convocation at 4 P.M. on Friday was then read by Dr. Hoadley, after which the

assembly adjourned to the Bellevue-Stratford for lunch. At half past two the Sectional meetings began.

Sectional Meetings

At the Hall of the Institute on South Seventh Street the meeting was under the chairmanship of Rear-Admiral W. A. Moffett, who is in charge of the U. S. Navy Air Service.

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Professor Joseph S. Ames of Johns Hopkins spoke on "Recent Developments in Aëronautics." "The research of men of science," he declared, "has supplied the exact mathematical formulas for building up the nearly perfect airplane." And he went on to show that this information in regard to air-pressure, viscosity and other aëro and hydro dynamic forces has conquered fully fifty per cent. of the work. "It is the purest application of mathematical knowledge in practical engineering development that I know!"

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Major General Mason M. Patrick, Chief of the U. S. Army Air Service, told of "Military Aircraft and their Use in Warfare." He described

how dirigibles carrying airplanes ready to launch may go to a great height and then release their cargo for their mission of reconnaissance and destruction. Airplanes may be equipped with automatic control and so be operated in large numbers by one man, whether high in the air, on the ground, or on a ship. They may be sent man-less in great numbers on bombing expeditions and thus defeat anti-aircraft provisions. "Transporting two million men across the sea without mishap during the war was a marvelous undertaking," said he, "but one that could not be repeated, due to the development of the giant plane." Again, because the planes—all kinds, from the light small observation to the giant bombing planes—have attained a speed of 150 to 250 miles an hour, an air-service stationed along the coasts and in different parts of the country could protect the U. S. much better than a navy, a matter which has been proved. The round-the-world fliers who were just completing their flight at the time of his address had their trips planned for them by the General and his office corps.

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Major General George O. Squier of the U. S. Army read a paper on "Electrical Communications for Military Purposes." "Progress in military art," he said, "consists in the realization of certain fundamental conceptions from time to time, and the seizure of one idea at a time, working it out in detail and applying it before an enemy realizes its importance. The nation that first takes hold of a new fundamental idea in war and works it out thoroughly in time of peace, possesses an insuperable advantage when suddenly a conflict is precipitated.

"In the World War the Central Powers introduced three such new instrumentalities: the Zeppelin airship, the super-submarine, and gas. The Allies introduced the tank. It is probable that if either side at the outbreak of the war had had any one of these instrumentalities in sufficient quantity, the issue would have been quickly decided by it alone.

"If unhappily war should come again, who shall say what limits to impose on a new idea of attack? Just as we now give a harmless anesthetic to a patient for a surgical operation, so we may be able in future to put a whole nation to sleep for forty-eight hours by a com-

bination of new chemical discoveries with radio-controlled man-less airplanes.

"The essence of strategy is surprise, which can be attained only by secrecy. The recent achievements by radio by which the world-wide inter-broadcasting is being accomplished, make it every day more difficult to preserve secrecy in the development of any new idea, in peace or war. A world-wide net of electrical communication, linking together radio, landlines and submarine cables in a new-born spirit of closest coöperation, must be developed to the limit of possible usefulness, both for the needs of peace and as a powerful agent for the prevention of war."

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Brigadier-General John J. Carty was the next speaker, with "Progress in Telephony" for his subject. He is a Doctor of Science, of Laws, holder of many distinguished orders and decorations, and his comment is recognized internationally as about the last word in telephony. He is Vice-President of the American Telephone and Telegraph Company, an organization which spends more for research and employs a larger corps of men in its laboratories (some 3000)

than any other. Now note, please, a curious sequel to research in business affairs. For many years Dr. Carty has been in charge of all scientific investigation by the Telephone Company, and Dr. Jewett has been in charge of the great New York laboratory in which the Western Union Telegraph Company also participates. But Dr. Carty is Vice-President of the Telephone Company, and Dr. Jewett has become Vice-President of the Telegraph Company. The reason for this is not far to seek: the presence of a man of highly specialized scholarship on the Board of Directors prevents the bankers, lawyers and merchants who are also members of the Board from opposing what they cannot understand. It is thus that errors of judgment that would prove costly, if not fatal, are avoided.

Dr. Carty began with the crude Bell instrument of 1876, and traced out the betterments and advances by slow, painstaking processes of thought, computation and experiment until the present state of the art was reached. He said that an actual wireless outfit was shown at the Franklin Institute electrical exhibition in 1884, but it failed to be developed until

many years later. The original idea, however, was there.

The Department of Development and Research of the Telephone Company, of which Dr. Carty is the head, also had humble beginnings. At first it consisted of one man, then two, and to-day it has a personnel of some 3000 workers, about half of whom have scientific training, while the remainder are draughtsmen, mechanics and clerks. At one time they had but one small room, and it was hard work to maintain even that. Now they boast a thirteen-story building with ten acres floor space, and an annual budget of over $8,000,000 for development and research alone.

In 1875 the entire telephone plant of the world could have been carried in the arms of a child. It consisted of two crude telephones and about 100 feet of wire, over which Alexander Graham Bell spoke to his assistant, Thomas A. Watson. In 1915 these two men again spoke together through the original historic instruments, although one was in San Francisco and the other in New York. And in the U. S. alone the system comprehends over 34,000,000

miles of wire, and over 15,000,000 telephone stations. The plant is conservatively valued at two billions of dollars. And it employs 450,000 men and women.

The staff of the laboratories transmitted for the first time the human voice across the Atlantic Ocean, from Arlington to Paris, and from Washington to San Francisco and to Hawaii, all without the use of wires. But still higher achievements now lie before them.

In regard to the actual value of the work done in this great laboratory it would be hard to determine. But the speaker had had a survey made of the work done during the period of 1900 to 1920. He chose only ten items concerning which data could readily be obtained, and the specific savings effected by these ten developments alone were found to amount to no less than $500,000,000. This means that if these late improvements had not been available, the cost to construct would have been that much greater.

It is constant, intense, scientific research that explains America's leadership in telephony.

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In Lecture Room 216 of the Engineering Building of the University of Pennsylvania Dean Howard McClenahan presided. The first paper was by Professor W. Lash Miller of the University of Toronto, "Concentration and Polarization at the Cathode during Electrolysis of Copper Salts" being his subject. Professor Miller is one of the leading teachers of physical chemistry on the American continent. The list of those who have studied under him includes a considerable number of scientists of the highest rank.

To the layman a solution is a simple thing: just something dissolved in something else. But to the chemist it is full of perplexities. For some seventeen years Professor Miller has been working on the behavior of copper salts in solution, especially when an electric current is passed through, and he has also put his best students to work at it. There are problems of concentration at different parts of the container, and a vast number of physical properties which, when carefully observed, are important to the great store of human knowledge. When these facts are duly recorded they become valuable to men engaged in research. In time

such observations are brought into use to lower costs, and to shorten and improve processes in industry.

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Professor Julius Stieglitz of the University of Chicago explained his "Theory of the Color Production in Organic and Inorganic Compounds." It is the result of long research, at once painstaking and brilliant, in which he has been able to account for the color of the countless dyes and pigments, for their variations in depth and intensity, as well as for the occurrence of color generally. It is not only a drastic change from the theory of O. N. Witt of forty years ago, but it enters far more profoundly into the subject, and provides the chemist with a complete working hypothesis. It should be of great value in the synthesis of dyes and pigments.

According to the wave theory of light the sensation of a definite color may be produced in the retina of a normal eye in two different ways. By what we may call the direct method, certain waves of a definite and limited length produce the sensation of violet. If they are somewhat longer the sensation produced is

blue, and with increasing wave lengths we get green, yellow, orange and red. Red calls for the longest visible rays.

The range of light waves goes far beyond that which is visible: some are shorter than violet, as the ultra-violet, which have powerful effects but are not visible. X-rays are shorter still. Similarly there are longer waves than red, also invisible. The shorter waves are noted particularly for their heating qualities and the very long ones are the Herzian waves used in wireless.

Direct color sensation depends on the emission of light waves of definite length from some source, as, for instance, in fireworks. The burning or oxidation of strontium salts produces a crimson light, barium salts give green, and so on. Direct production of color usually requires a high temperature.

Cold objects usually give the sensation of color by the indirect or what we may call the compound process. All the visible light waves range in length from about 1/60,000 to 1/30,000 of an inch in length, and altogether they give the sensation of white. Then suppose the surface of an object absorbs only the shortest

wave lengths from the white light, that is, the violet light waves. So far as the human eye is concerned under that condition, the violet waves are absorbed and it does not see them. The sensation produced on the retina is that of a greenish yellow; hence violet and yellow are called complementary colors. Cyan-blue and orange, a bluish green and red are other complementary pairs. Practically all colored objects that we see show us the complementary colors of the rays absorbed. Therefore by the absorption of the shorter wave lengths we see yellow, orange and red colors, while by absorption of the longer waves we obtain violet, blue and green.

The emission of colors is akin to the production of sound: we speak of color harmonies as we do of tonal harmonies. Pure tones result from pressure waves of definite length produced in the air by regular disturbances, as by the vibrations of a violin string, while pure colors, according to the wave theory of light, result from waves produced in the ether by regular electro-magnetic disturbances.

For the production of color by emission, or by the direct method, a source of vibration is

also necessary. As visible light waves move at immense velocity,—nearly 300,000 kilometers a second,—the vibrating particles that start the waves must be capable of very rapid oscillations, and they must be very small. They are found in the *electrons,* the negative particles of electricity which have a mass of only 1/1800 of the hydrogen atom, the smallest atom known. All atoms of all elements are composed of these electrons which oscillate about a nucleus containing free positive charges of electricity at the centre, and the electrons of the atom of strontium, for instance, at a high temperature vibrate so as to produce light waves which affect the retina as crimson, and the electrons of barium under the same conditions will start light waves which we see as green.

For the production of color indirectly, by absorption of parts of white light, we must also have particles capable of vibration which, under the impact of white light, are started vibrating by certain of the waves in such a manner as to consume the energy of those waves, and thus to destroy or weaken their effect while other waves pass on. We may get a notion of this from a tuning fork keyed to

A which will give the tone A from any passing air wave of the tone A. It is suspected that electrons in colored objects must be the vibrating particles which respond to trains of waves of white light and absorb parts of them, thus giving rise to the complementary colors.

It is just which atoms in the complex dyes and pigments that contain these color-producing electrons; why many objects should be colorless and why others should be so intensely colored; that has been the subject of Professor Stieglitz's study. His researches seem to reveal an exceedingly interesting connection between color, color depth and color intensity,—with what is known to the chemist as oxidation and reduction; the fundamental chemical phenomenon on which the maintenance of life and the combustion of coal depend.

In the oxidation of iron to iron rust, for instance, the fundamental change is that the iron atoms, each of which is made up of a number of positive charges in the nucleus, and an equal number of electrons oscillating about the nucleus, lose certain of their planetary electrons to the oxygen atoms in the surrounding air. Then the iron atoms, having lost some

of their negative charges or electrons, retain an excess of positive charges in their nuclei and are thus positively charged while the oxygen atoms with an excess of electrons become negatively charged. Then, as oppositely charged electrified bodies have an extraordinary attraction for each other, the positive iron and the negative oxygen atoms cling together and become iron oxide or rust. Now according to Dr. Stieglitz we have here two atoms in closest juxtaposition, one positive with oxidizing power, and the other negative with a surplus of planetary electrons. Then the attraction of the positive atom for the excess electrons of its neighbor *loosens* these from the ordinary restrictions of intra-atomic force to such an extent that when a beam of white light passes through the pair of combined atoms, the loosened electrons vibrate and absorb some of the waves while the rest pass on and are seen as the complementary color. It is this loosening effect which is fundamental and it represents a stage just short of the actual passage of the electrons from atom to atom: a step just short of the final oxidation and reduction. Thus iron rust or oxide is red because

the electrons of the oxide atoms tend to pass back into the iron atoms, but their wavering under the influence of light absorbs the green waves and leaves the complementary red-brown color. One example will do as well as many; the point is that the electrons of the negatively charged atom in a compound are loosened up by the presence of the adjoining positively charged atom so that under the influence of light they find a new orbit. Then according to the nature of their surroundings, the only available orbit is consonant with a certain color, whereby that particular color is absorbed while its complementary color passes on to the eye of the observer. The other pairs of complementary colors present in the white light, being completely present and not at all absorbed, remain invisible.

Dr. Stieglitz's method not only accounts for the presence and the nature of color found in the whole range of known dyes and pigments, but also explains why it is lacking in such substances as table salt, chalk, gypsum, etc.

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Professor E. G. Coker, head of the Department of Engineering of University College,

London, made by means of an elaborate apparatus a remarkable demonstration of "Photo-Elasticity" the fruit of some fifteen years' work by him and his associates. Modern physical science is constantly striving to get a closer and more intimate knowledge of the inner structure of matter. And in engineering the constant question is to know what is the stress or strain at every point of an apparatus or structure. It can only be figured out when the engineer knows exactly where the strain will come, and here is where he is likely to make a mistake. In discussing his invention Professor Coker said: "We make a celluloid model of the object to be studied, whether it be a cog-wheel, a brace, or a beam of structural steel. Through this model we project polarized light which immediately breaks into the colors of the rainbow. The way it breaks enables us to make a map of stress and of the direction of the stress at every place, so that the engineer can find just where weakness lies in his device. The results are applicable to steel and other metals, and are very easy to apply."

This invention is now being used in making electrical apparatus and the U. S. Government

also employs it to study stress in aircraft in the hope of remodeling the designs and cutting down loss from breakage. In the long run great saving should be brought about by this means in building, designing and operating any new bridge or other structure.

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In Room 226 of the Engineering Building Professor Dexter S. Kimball, Dean of the School of Engineering at Cornell University, read a paper on "The Progress and Promise of Engineering." He began by calling attention to the popular conclusion that civilization has developed as man has invented tools and discovered processes through which to control his environment and satisfy his needs. The ancient Hebrews, when invading Palestine, admitted that they could not drive out certain inhabitants "because they had chariots of iron." The situation to-day is unchanged in principle.

But man does not advance by tools alone. He must control his tools. And he must be able to transmit intelligence. Here lies a difficulty. Until recently discoveries and inventions were made and applied by the same individual. Now one discovers, another de-

velops, and the engineer applies. This calls for familiarity with human experience, and also for inventiveness among all three. The great contributions of engineering to human progress were noted. But advance has been far greater along the lines which extend man's comfort and convenience than in the development of his intellect. The ideals of ancient civilization were ideals of necessity. By the development of man's power over nature it becomes possible to look towards a condition of universal well-being, proper housing, with at least some measure of spiritual and mental development. This is the great hope of the present age, such advance being of far more import than material progress.

While we are as yet far from the realization of such a happy condition, the speaker's argument was to the effect that progress in science and in its application gives warrant for the hope. In material development certain things are still to be attained:—an unlimited supply of power from the energy of the universe, and, concomitantly, a method of producing synthetically from oxygen, hydrogen, carbon, nitrogen in association with other elements, necessary

food combinations. These discoveries Dr. Kimball said may be a long way off, but in time they will be made. Then we shall have at least the facilities for Utopia, but even so, unless we develop understanding and sympathy and character, we shall be without the civilization, the government or the body and instrument of law to meet the situation.

Of course such advances in science would also multiply the weapons of destruction as well as the means of welfare. We need both faith and character to carry us past such potentialities of terror.

It is true also that the evils of modern industry, which is the child of scientific development, are in some measure offset by the benefits conferred by it. Congested industry and division of labor may be held principally responsible for the evils. Agriculture has been separated from the mechanic arts, and a complex system of transportation has been introduced with such elaborate means of intercommunication as to render human relations inordinately complicated. This brings about many perplexing obligations, some of which are not yet even recognized.

These inventions, however, are not failures, nor are they in themselves destructive. The way to betterment lies in applying to our difficult social, industrial and political problems the same method of attack by which the engineer and the scientist make progress. It is the scientific method of reasoning that furnishes us with our leads. While engineers cannot solve all the riddles, they can give potent aid. Industrial management is rapidly passing into their hands because they have adjusted themselves to the arts of administration and scientific control. The wider the engineer's field of understanding the better is he likely to succeed, really to succeed, and not to make profits at the cost of human welfare. Business administration is now recognized as a science, and taught as such. The key to improving industrial organization is to entrust it only to those who have proved themselves competent by study, coupled with experience. In many successful establishments this has already been accomplished.

The body and practice of law invariably improves with an advanced mode of living, and we look forward to a more scientific grasp of

legal questions as time goes on. Government still lacks adequate administration, but with a firmer hold on industrial matters it is fair to believe that this will follow. Great changes are needed to bring about more intelligent leadership and less rule by popular vote, which is, in effect, the rule of passing fancy or emotion, and not that of wisdom. Here lies a great opportunity, both for scientist and engineer. They of all people possess classified knowledge and the ability to bring about the better order. The law of diminishing returns did not worry the speaker as a menace to civilization, so long as progress is made in the application of rational thought.

Thus far we have only been blundering along, with results that are not wholly reassuring. But if we will apply the philosophy of science we may yet look to the realization of ideals far higher than those which now obtain.

In conclusion Dean Kimball laid the greatest stress on the need of high ideals. Without these, without nobility of purpose, advancement in science may become a curse rather than a blessing. The whole store of scientific knowledge is for the use of mankind, to the end that

a better and higher order of living may obtain. Without such nobility of purpose in the application of scientific discoveries the greatest achievements may degenerate into instruments of wrath that lead only to destruction.

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Mr. Daniel E. Moran, C.E., M.Sc., of New York, spoke on "Some of the Effects of Loading Granular Material." This talk, illustrated with lantern slides, was replete with valuable information for engineers.

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Brigadier General Edwin Jadwin, U. S. A., in "Modern Military Engineering," pointed out that military engineers have been responsible for victories in war from the time of the ancient Greeks down to the present. He outlined more particularly the contributions of army engineers to the engagements in the late world war.

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Under the chairmanship of Dr. Arthur L. Day in Room 340 of the Engineering Building, Dr. W. J. Humphreys, of the U. S. Weather Bureau and formerly of Johns Hopkins, told of "The Way of the Wind." In its beginning this lecture seemed rather simple. Said Dr.

Humphreys, "The mathematics of the problem is almost the a b c of physics," but as he went on to reveal the number of factors that influence the ways of the wind we learn that it does not behave at all as we should expect from laboratory experiment, and the subject becomes no less than bewildering. A current of air headed from the North Pole for New York will be deflected by the rotation of the earth to Boston. Its direction is usually that of a comparatively small curve. There seems to be no limit to the possible velocity of a cyclone, but the velocity grows less and less as it approaches the pole. The friction of the earth's surface forms one impediment to the wind's velocity. Wind and water do not drift in the same direction at the same time, but at an angle of 45° apart. As soon as we understand these phenomena, however, they cease to be unreasonable. Let us consider the air as a mineral that is lodged in layers above the earth, just as coal is lodged beneath its surface. The air moves about for two reasons: differences in temperature, and because the earth turns. It was at first supposed that the winds were wholly unreasonable and contrary to all common sense. But by borrowing

an idea from "Egmont" we are able to perceive that there is method in their apparent waywardness. Why do ocean currents flow in different directions from the winds that blow over them? This question puzzled us until calculation solved it. Even when winds blow in opposition to currents and at greater velocity, it is all in accordance with the mathematics of the subject. Only a beginning has as yet been made in this exceedingly complex study, but the speaker prophesied that in time it would be so advanced as to be of signal service to meteorology.

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Dr. William E. Coolidge of the General Electric Co. spoke on "Modern X-ray Development." It may be remembered that it was Dr. Coolidge who gave us ductile tungsten, and thus delivered us from the old carbon filament electric lamp. At least Dr. Whitney, who is head of the General Electric Laboratory, says so, but Dr. Coolidge in turn insists that much credit should go to Dr. Whitney. The latter refuses to admit this, but no bad blood is begotten by such a pretty quarrel. In the field of X-ray tubes Dr. Coolidge has been leader in

research in the U. S., and he is an international authority on the production of X-rays.

The uses of X-ray apparatus have gone forward by leaps and bounds. The remarkable statements made by Dr. Mees, elsewhere

Mr. George L. Clark of the Research Laboratory of Applied Chemistry at the Massachusetts Institute of Technology has lately published a paper on "The Versatility of X-rays" in Tech Engineering News of Dec., 1924. Here are some of the uses mentioned: destruction of abnormal growths in the human body, diagnosis of disease, industrial diagnosis, as, for instance, the determination of the safety of bridge and building steel girders, steel rails, plant equipment and the discovery of cores, gas pockets, sand and slag inclusions and "pipes" in metals; spongy metals, cracks, etc. Faulty castings may be rejected and sound castings sometimes made to replace forgings by this agency. Examination of Coal for Slate inclusions is another use. Other X-ray utilities include the location of pipes hidden under walls and floors; discovery of hidden wires by electricians; location of beams and nails within walls by carpenters, and the discovery of concealed articles by Custom-House Officials. Some experiments in hastening the germination of seeds have given positive results. X-rays also produce coloration in glass, white topaz, amethyst and other stones used in jewelry. They cause many substances to become luminiscent or fluorescent, and they provide for the immediate detection of the differences between a diamond and its glass counterfeit. A promising field is the activation of catalysts. A platinum catalyst used in the contact process for making sulphuric acid was increased in efficiency no less than 35% at a temperature considerably below the optimum range. Another field offering great possibilities is in chemical reduction. Like ordinary light X-rays reduce the electrical resistance of selenium. The disruptive potential of an explosive reaction is lowered by X-rays. Monochromatic X-rays are far superior to arcs or radium for ionizing gases. Anodic polarization is materially increased by X-rays with consequent application in electrochemical processes, as in the oxidation of organic compounds.

Photochemical reactions invite the study of X-rays, because the wave lengths and intensities may be readily controlled. The oxidations of benzaldehyde, rubber and oil are accelerated to an enor-

recorded, on X-ray photography, will doubtless surprise many persons.

A simple portable apparatus shown by Dr. Coolidge may be attached to an ordinary electric light connection, and X-rays may then be produced by merely pressing a button. This

mous extent if X-rays are permitted to enter the reaction vessel. Corrosion of metals is profoundly affected by X-rays, as well as by ultra-violet light. It may be possible to render surfaces passive and to study the mechanism of corrosive action by this new method.

The Braggs, father and son, have told of X-rays and crystal structures. The crystalline structures of over 150 inorganic salts have been determined, long soap molecules have been measured, and the differences between tartaric acid and its racemic forms are made clear. The X-ray method has resulted in the production of single metallic crystals of great size which have properties wholly different from the crystal aggregate metal. In the study of alloys and solid solutions the past two years have shown more progress than all the previous ages. The true constitution and structural changes of steel, brass, bronzes and other common alloys are disclosed. Technically the uses of X-rays include the examination and testing of coal, leather, soap, starch, sugar, textiles, rubber, paints and ceramics, to name but a partial list. Glass and fused quartz are tested for incipient deterioration, which is of extrordinary usefulness in the manufacture of fine lenses and mirrors. Indeed, a whole new method of chemical analysis is thus provided.

There is a promising field of work on absorption films, oriented surfaces, electrodeposited metal films, corroded surfaces and the structures of the surfaces of catalysts.

Precipitation is brought under control by X-rays, dimensions are studied and determined, as well as the relation of crystal structures to the refractive index and other properties. Secondary valence is confirmed, and the importance of atomic numbers is demonstrated. Study with X-rays leads to the making of atomic models, confirms the Combination Principle, points to the discovery of new elements, fixes the number of electrons in an atom, among other marvels. We have as yet merely entered upon the great romance of discovery which is opened up by this remarkable means of research.

apparatus differs from its predecessors mainly in that it is exceedingly small, simple to operate, and entirely free from the usual danger of electric shock. It was developed especially for the dentist, for making pictures of teeth. In the medical field it can also be used where extreme portability is desired, as for X-ray work in the home of the patient. It is also useful in college laboratories for demonstration purposes, and in industrial laboratories wherever X-rays are desired for short periods of time. Such an outfit also makes it easily possible for the building contractor to see hidden timbers, piping and wiring in partition walls and floors.

The outfit itself is hardly larger than an ordinary box camera.

The speaker outlined some of the improvements which have been made in X-ray apparatus, more especially the tube, since Roentgen first startled the world with his wonderful discovery. He told of the substitution of ductile tungsten for the platinum of the earlier targets, and discussed the different methods employed for cooling the target. He also dwelt at some length on the effect of the design of the tube upon its performance.

Water-cooled tubes have been made to support 250,000 volts at 50 milliamperes in continuous operation.

To obtain X-rays of shorter wave-length and hence greater penetration, tubes have been made with targets of thorium and uranium.

To get still shorter wave-lengths it will be necessary to develop tubes for voltages above 250,000.

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Professor William Lawrence Bragg of the University of Manchester spoke on "Inorganic Crystals." He is one of the pair widely known as "The Braggs." They are not brothers, but father and son, the senior, Sir William H., being head of the Royal Institution of London, in the chair of Faraday, while the son is professor of physics at the University of Manchester. Their names are known wherever physical science is studied earnestly, for their classical work on the nature of crystals. Improving upon Laue's method of detecting atoms by X-ray analysis, they have discovered how the atoms arrange themselves in a lattice formation, and in crystal units, being held together by valence or by electrostatic force. For many

years the forms of crystals have been studied, but the question of why they form, as if at the whispered command of nature, into definite geometrical shapes, has been a puzzle throughout the centuries. The Braggs are constantly telling us more of the internal arrangement of crystals, and they are the first to have done this. The speaker propounded the question why the same substance will crystallize, sometimes in one form and then again in another. As an example he cited calcium carbonate which is sometimes found as calcite and again as aragonite, two entirely different crystal forms of the same substance. He displayed models on a scale of 1,000,000 to 1, and his talk became both exciting and convincing as he reached the conclusion that weather conditions alone may be held accountable for the crystal form. Again his exposition of his hypothesis, why certain crystals show double refraction, was as thrilling as it was conclusive.

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Wednesday evening was given up to private dinner parties.

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On Thursday morning at ten o'clock in the Harrison Chemical Laboratory, Dr. Willis R. Whitney of the General Electric Co., Schenectady, presided over a notable meeting.

Professor Fritz Haber of Berlin was the first speaker on "Technical Results of the Theoretical Development of Chemistry." Inasmuch as he had a long series of mathematical equations to write out on a blackboard, and was very busy doing so, Dr. Whitney took the occasion to improvise a few remarks on pioneers. The Indian who first chipped an arrowhead, said he, was a leader in research. If we become able to eat corn husks and digest wood, there will be more things to do, a greater variety of useful things to do than we can find to-day. Lord Kelvin said he had learned more by talking than by any other means, and this is hardly surprising, because we have been talking for hundreds of thousands of years, whereas we have been working constantly at research but a few centuries. If one thinks and does not talk, what he thinks may never be born. Then, Professor Haber being ready, he presented him to the audience. It was Dr. Haber who taught the world to fix nitrogen economically. All liv-

ing organisms contain nitrogen and require to be fed nitrogen constantly. Stable manure contains it, but there is not enough of this to fertilize all the fields, so we have to depend on Chile saltpetre, which is nitrate of sodium. Nearly all explosives contain nitrogen, so that we cannot grow our crops in peace or fight through a war without its help. Accordingly, towards the end of the last century the great problem was to fix it. That is, 4/5 of the air is nitrogen, but so closely together are the atoms bound within the molecules that they cannot be pried apart, wherefore the nitrogen of the air is inert, and will not combine. The micro-organisms of leguminous plants bring a little of it into combination, which is the reason farmers sow clover or cowpeas or similar crops and plough them under for fertilizer. But that takes time. One of the early efforts of the twentieth century was the Bradley-Lovejoy experiment with the electric arc to combine oxygen with nitrogen at Niagara Falls, but that was abandoned by the capitalists before it reached a successful issue. Then some Norwegians backed by English capital took it up, and they organized a very successful establishment in Norway

where water power is plentiful and cheap. But water power is growing too valuable to be used in such vast measure as is called for by this process. And Germany has very little of it. So Dr. Haber proceeded to take nitrogen from liquid air by distilling it off and bringing it together with three times its volume of hydrogen obtained by electrolysis of water or other means; to bring the two together at great pressure and high temperature in the presence of a catalyst, and, presto, there was ammonia! Combine ammonia with sulphuric acid and there is a great fertilizer. Oxidize the ammonia to nitric acid, and there is the one thing needful to make explosives. Had not this invention of Dr. Haber's been already worked out to successful and economical practice in Germany, the Central Powers might have had difficulty in fighting the war, because the sea was closed to them, and they could not get Chile saltpetre. Their coke oven ammonia was restricted in output and the other processes did not serve so well. The Haber process now furnishes Germany and her export trade with abundant fixed nitrogen. It is the basis of substantially all the ammonia processes. And Haber did it.

Having announced that he would touch only on the important features of the subject Dr. Haber began by saying that the literature of science sets forth results, but seldom the causes of development. The theory of one generation becomes the practice of the next. Then he showed how chemistry goes forward step by step, accordingly as our field of understanding is enlarged. Thus within his own lifetime he has observed three periods of advancement: the first when chemists were absorbed with the structure of molecules and how atoms were connected; the second when chemistry became dynamic and ideas of energy supplanted the prevailing conceptions of status. In the third period which we are now entering the chemist has to consider particles far smaller than atoms which are constituent parts of atoms, the electrons, and has come to deal with atoms of energy and with quanta.

In connection with the second phase also the chemist is entering the domain of life in colloid chemistry since he is learning the laws of cell membranes, the contents of which form the principal substance of living beings. The

theory of adsorption in colloid chemistry owes its existence to Willard Gibbs.

If some new source of energy is discovered that will free us from our roundabout method of burning coal or oil to develop it, the synthesis of food may follow, with the possibility of living on the stalks and husks of corn instead of on the seed alone, as we do now. The speaker referred to Dr. Cottrell's great contributions to colloid chemistry in the conquest of fumes, dust and smoke by electric precipitation. Then, after an elaborate outline of possibilities, he proceeded to a mathematical demonstration of things done in the field of general chemistry, with quotations from Gibbs, Guy Lussac, Helmholtz, Langmuir and others in support of his derivations of chemical equilibria.

Again, he discussed the opening of the door to the understanding of the phenomena of crystallization in connection with the chemistry of life, and of ionic clouds and molecular layers, and other phases of research. We must always search closer and closer to nature, he said, and, to achieve this, progress demands the intimate cooperation of men of science of all countries.

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Dr. Haber was followed by Dr. Arthur L. Day, Director of the Geophysical Laboratory of the Carnegie Institution, who spoke on "Some Causes of Volcanic Activity." Dr. Day is one of the leading enquirers into the physical development of the earth. He said what he had to offer was a rather comprehensive study of its pioneer stage. Volcanic activities are the last workings in the sequence of formative processes which have built up the earth's igneous structure. The phenomenon is characterized by a constant shifting of conditions not in equilibrium. It is accompanied by many conditions that cannot possibly be reproduced in the laboratory.

There are not many volcanoes left, and these behave like separate units, not like "safety-valves" of a continually molten interior. They resemble honeycomb structures, containing cells of unsolidified rock. We conclude from their phenomena that the earth's center is not fluid, but rigid; as rigid as nickel steel, otherwise under the pressure developed the form of the earth would be distorted.

Volcanoes differ one from another. Some develop great heat, and others do not. In Hawaii

Dr. Day saw liquid slowly pushing up from a crater and overflowing the ground without any disturbance. This is the simplest form of volcanic activity. Again, in Hawaii he collected the original gases out of the liquid lava from a volcano, and these were over 1000° C. in temperature. They contained sulphur, water vapor, carbon dioxide, and hydrogen. They could not be in equilibrium at 1000° C. They were in process of reaction at the time, and the reaction of every succeeding moment differed from the others. Indeed it was the reactions that caused the heat.

In the eruption of Vesuvius in 1906 water was largely contributory to it. There was an open liquid column that rose from 3 to 4 thousand feet above the sea, and its temperature was probably at the maximum at the top, owing to the reactions which took place en route.

The causes of volcanic disturbances seem to be due to the crystallization of theretofore amorphous material under the earth's surface. From the chemical analysis of rocks which, because of rapid cooling, are uncrystallized, we learn that they sometimes contain 4 to 8% of water. On the other hand, the crystalline rock

never contains over 1½% of water, and seldom more than 1%. Now if so much water is contained in the magma which is crystallizing within the earth, the process must be accompanied by an ejection of water. If the crystallization takes place rapidly in an enclosed space the pressure must be immense, and if the quantity of water ejected is large a violent eruption is likely to follow. If crystallization proceeds more slowly successive eruptions may continue for considerable spaces of time. Dr. Day instanced that of Lassen Peak which continued intermittently over a period of four years (1914-17). Rain and snow sometimes collect in the crater, and when there is a weakening of the walls of this the water will seep through, and violent manifestations ensue. Sometimes the top is cracked by an earthquake. Sometimes the side weakens and then lava may flow down.

If the temperature is low this signifies that the crystallization is proceeding slowly. Increase of water will accelerate the rate of crystallization. Instances were cited of recent borings in northern California where the temperature of boiling water was reached 3 feet below the surface. And when they got

down to 373 feet the equivalent of 1100 kilowatts of energy was obtained from two borings. Dr. Day suggested that there was a possibility of developing power on a commercial scale from borings in such regions where the internal heat of the earth would help to do the work of the world that is going on at its surface.

A series of remarkable slides, photographs of volcanoes in action, illustrated this interesting discourse.

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Professor Wilder D. Bancroft of Cornell University was next, with an address on "The Development of Colloid Chemistry." He is a Harvard man, suave, witty, with a broad vision, profound in scholarship, and gifted with an amazing memory. George Bancroft, the historian, was his grandfather. Chemists always crowd in when he lectures, and so would the laity if they only knew of his powers of exposition and his faculty of making his subject interesting.

Primitive chemistry, he said, was essentially descriptive. Then came the development of atoms and molecules, followed by the study of organic chemistry and the carbon compounds,

then physical chemistry with thermodynamics and the mathematical computation of reactions. The latest is the great branch of physical chemistry known as colloid chemistry. Baudrimont and Selmi thought of the chemistry of non-crystalline substances before Graham, while Cary Lea of Philadelphia also had ideas in regard to the subject later, but they were not believed. It was Graham who put it over. Why is it, asked Dr. Bancroft, that some chemists can get at once a hearing and a following while others fail in doing so? In this instance the answer lies in the fact that Graham introduced dialysis. In dialysis the chemist separates solutions of mixed substances by taking advantage of the different diffusibilities of each substance to pass through moist membranes or septa. "You can't," said he, "put anything across unless you can give the other fellow something to do with it." And he gave some amusing experiences to prove his point.

Colloid chemistry is the chemistry of bubbles, drops, grains, filaments and films. All colloid phenomena involve adsorption, and in adsorption particles cling either on the surface or as separate films. Many colloidal

phenomena are affected by electric charges; indeed electric charges and Brownian movements are the very basis of colloid chemistry. Emulsions are drops of one liquid suspended in a second liquid, and the type of emulsion depends on the stabilizing medium, and not on the relative volumes of the two liquids. We can emulsify water in oil, and oil in water. We can even emulsify as much as 90% of oil in water by means of a little soap.

By peptization we loosen the smaller particles by adding chemicals or by mechanical or electrical disintegration. Thus ordinary washing with soap is a particular instance of peptization.

Ordinarily we don't care how or why anything is adsorbed. All we want is to get it on, as in painting or printing, or to get it off, as in washing. But to get the best results we must know just why each event that we want to master is brought about. We must study what bonds are opened in adsorption, because that will give us the reason why some things don't stick on. Then, when we know precisely what forces are at work, together with the nature of our materials, we can control the situation. The amount of work that is crying to be done

in the way of getting more information than we now possess is immense. Dr. Bancroft cited only a few of the familiar activities of humanity included in the domain of colloid chemistry. There is everything relating to bubbles, as in flotation, for instance, in which the metal (sulphides) attaches itself to the oil film surrounding the bubbles and is carried on to the top and skimmed off while the rock sinks to the bottom because the oil does not wet it. Again, bread is an industry of bubbles. In phosphate baking-powders the acid, which is usually calcium monophosphate, must be protected by cornstarch, or else it would act too soon on the bicarbonate of soda and generate the gas before it was put into the dough. Then we should have unleavened cake. There is a floating kind of soap which floats because of the bubbles it contains. The more bubbles in a cake of a given size the less soap does it contain—and air is cheaper than soap. The same rule holds true of the new fluffed ice-cream. When hair grows white it is due to bubbles forming in the follicles, at least in the case of all animals. There is no white pigment in it. The blue feathers of birds contain no blue pigment. The sunny gleams

in opals and pearls that are like the clouds of dawn arise from colloidal films. Colloidal films give the peacock his gorgeous tail and colloidal solutions give some of us blue eyes. On the other hand, paints are held on by colloidal films.

Photography, printing, rusting of metals, cements, crayons, pencils, ceramics, clouds, dust, sewage, textiles, all are colloidal. We run against it everywhere.

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The meeting was closed by Dr. C. E. K. Mees of Rochester, N. Y. Dr. Mees is director of Research and Development of the Eastman Kodak Company, and is generally recognized as an authority upon photography. Born in England in 1882, he studied at University College, London, and took there the degree of B.Sc., in 1903, and in 1906 that of D.Sc. by research in photographic processes.

"1924," said he, "is not only the centenary of the Franklin Institute, but is approximately the centenary of photography itself."

About one hundred years ago Nicephore Niepce of France discovered that if a plate is covered with a layer of bitumen and then ex-

posed to sunlight, the bitumen becomes insoluble in solvents which will dissolve it if it has not been exposed. Niepce coated metal plates with the bitumen and after printing an image on them etched the image into the metal and then printed the metal plates in ink upon paper, so that this was not only the first photographic process, but, still more, it was the first application of photography.

Photography, Dr. Mees declared, is the handmaiden of all the sciences. It records both the seen and the unseen. It reveals radiations otherwise invisible, and serves as an essential tool in the measurement of light and other rays. Its use in astronomy is constant, and all observing astronomers are experts in photographic art. Photographs of the sun are taken by light of a single wave-length, with amazing results. Sun spots are shown on the solar surface under great clouds of hydrogen vapor. And enormous whorls of gas are observed to surround the spots. The seasonal snow-caps and markings on Mars may be photographed by this method and Barnard's black nebulæ are shown to be identical with other nebulæ, while not being hot enough to give out light. Photography

records the different colors of the sun and the spectra of the stars. And it confirms the Einstein theory.

Surveyors are using photography more and more. In mountainous regions maps are made from surveyors' photographs. In Rochester an aviator in a single flight made an excellent map of the city, not as complete, of course, as had it been worked out by triangulation, but at lower cost and with more accurate approximations than could possibly have been made by other means in so short a time.

In medicine color photography is used to depict cancerous tissues, and to preserve records of many other diseases. Incipient tuberculosis can generally be diagnosed by X-ray photography.

In physics remarkable results are derived from its use. The diversions of alpha rays in a chamber containing a small amount of water vapor are made evident because the particles, too small ever to be made visible to the human eye by any known instrument, leave tracks of condensed water behind them, if the temperature is suddenly lowered by expansion—and the camera catches these tracks. By X-ray pho-

tography the Braggs have made their startling revelations concerning the order and arrangement of atoms in crystals, and Aston owes his discovery of the isotopes of the atoms of many elements to the application of photography in a modification of Sir J. J. Thomson's positive ray apparatus. Projectiles going at high speed have been photographed, at speed so great that a bubble penetrated by the missile is caught by the camera before it collapses. Explosions and sound waves are recorded by moving pictures, and so are flames that are running at a rate of 20 metres a second.

The X-ray photograph is ever more and more widely used for chemical analysis. Impurities and defects in metals are detected by means of X-ray photography. Even golf balls are selected with the aid of the X-ray.

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On Thursday morning at 10 o'clock in Lecture Room 214 of the Engineering Building of the University of Pennsylvania, another series of lectures was presented, General Guy E. Tripp of the Westinghouse Company in the chair. The first speaker was

Professor P. W. Bridgman of Harvard, who

has been engaged for a number of years in determining the effects of high pressure on physical properties; in observing what changes take place in substances under high pressures. So many different problems have been covered by his experiments that he compared himself to a schoolboy with a new jack-knife, the blade of which he tries on every conceivable object. As his apology he explained that there seem to be very few jack-knives of the kind, or else very few persons who want to use them. Meanwhile there seems to be considerable whittling to be done. Indeed this work may be said to give us a new dimension in regard to the properties of materials which bids fair to come into general laboratory use. From it we get a new "line" on substances; a new way of recognizing their differences. This was a very practical contribution.

The pressures at which Dr. Bridgman has worked are not high enough, generally speaking, to effect great changes in the interior organization of the atoms. He used pressures of 10 to 20 thousand atmospheres; or from 150,000 to 300,000 pounds per square inch. So gentle a push could only crowd the atoms somewhat

closer together, whereas in the interior of stars where this force may extend to billions of atmospheres those factors would be present which are supposed to prevail at the evolution of the atom.

The changes wrought by the pressures available to us which result in this crowding of the atoms in such wise that they must give a more intimate account of themselves, are of necessity simpler than the changes resulting from a shift in temperature. If we observe the changes caused by pressure, just as for years we have observed those caused by temperature, we shall greatly increase the field of our knowledge; we shall have two dimensions for observation instead of one.

Here are some of the facts found, and a few of the implications, the paper being too rich in scientific deductions to give it in full: at high pressure in regard to changes of volume there is no essential difference between a gas and a liquid. Under 12000 kg. pressure the change of volume is about 20% for water and 33% for ether, while hydrogen and helium, which are the most compressible substances known to us, have a volume of less than when frozen

solid at atmospheric pressure and a temperature close to absolute zero. Under these conditions thermal expansion drops to less than 1/4 of what it is ordinarily, and compressibility drops from 1/15 to 1/5.

Organic liquids show a curious property: above a certain pressure the ordinary behavior of thermal expansion reverses itself, and the liquid is more expansible at low temperature than at high! Organic liquids behave much alike until the highest pressures are reached, when frequently their differences manifest themselves. These differences may be due to the shape of the atoms or molecules. But water, which under ordinary conditions behaves so unlike other liquids, seems to lose its abnormalities under high pressures.

The changes in volume of solid elements (mostly metals) are in general less than those in liquids, but they are of great moment. Usually the volume of a metal may be compressed by pressure to considerably less than would be possible if it were deprived of all heat motion by cooling off to absolute zero at atmospheric pressure. Some metals have great compressibility. Caesium, for example, loses

more volume than ether at high pressure. A characteristic difference between liquids and solids is that the latter do not lose their compressibility so rapidly at high pressures.

While compressibility becomes less at high pressures, there is an exception to this in quartz and several varieties of common glass in which silica is the prominent constituent. High pressures increase their compressibility.

From the evidence furnished by 37 substances there is reason to believe that Tammann's theory is wrong in assuming that there exists a maximum melting temperature above which a liquid cannot be forced to freeze, no matter how high the pressure. It appears probable that any liquid which contracts on freezing will succumb to the requisite amount of pressure at any temperature.

Solids and liquids become more and more alike in volume at high pressures, but the latent heat absorbed on passing from the former state to the latter is little changed.

That liquids are more compressible than solids seems reasonable enough, except in the case of ice, which has a bulkier volume than water, but remains less compressible. This

phenomenon of greater compressibility for the modification with the greater volume is not infrequent.

A transition interesting as it is unique is that of yellow phosphorus under pressure to a black modification akin to graphite. For 10 to 30 minutes before the change occurs there is a preliminary change that takes place throughout the entire mass which is accompanied by a slight loss of volume. It proceeds at an accelerated rate until the entire structure becomes unstable, finally collapsing into the new modification. We cannot inoculate a mass of the yellow phosphorus with the black and thus hasten or delay the transformation, which is irreversible.

The electrical resistance of metallic elements generally, but not invariably, increases under pressure, the rate of increase diminishing as this rises. Under 12,000 kg. it varies from 1% or less for a metal such as cobalt, to 70% for potassium and rubidium. Of a few metals the rate of increase advances as the presure increases. But with caesium the resistance decreases at first, passes through a minimum, and then increases. With antimony the resistance at

right angles to the original axis at first increases, passes through a maximum, and then decreases.

The thermal conductivity of most metals, but not of all, increases under pressure. In the case of the majority the change of thermal conductivity is less than that of electrical.

The effect of pressure on thermal conductivity of liquids is large: 12,000 kg. increasing it by two- to three-fold.

Long ago it was discovered at the West Virginia Experiment Station that high pressures will sterilize fats, but Professor Bridgman observed also that high pressure in the cold will coagulate egg-white and the proteids of meat.

These are merely some of the results secured by the lecturer in this new and unbounded study of the properties of matter under pressure. For fuller information the reader is referred to the complete paper which will appear in the extended report of the proceedings.

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Professor Dayton C. Miller of the Case School of Applied Science at Cleveland presented a paper on "The Phonodeik." Professor Miller was born in Strongville, Ohio, studied at Baldwin-Wallace College at Berea in the

same State, and received his doctor's degree from Princeton. He has been a Lowell lecturer at Boston, and is eminent in physics and astronomy. The Phonodeik is an apparatus of his invention for recording sound waves pictorially, upon a photographic plate, or for projecting them upon a screen for public exhibition.

The sound waves are represented by a wavering streak of light that accurately portrays a single tone or any combination of tones simultaneously. The vibrations are magnified from 2500 to 40,000 times. The records of sounds are made on a film somewhat like that used in a motion picture camera. "Pictures" may be taken of any sound, from that of a 14-inch gun, or the fortissimo of a symphony orchestra, to a faint whisper.

The instrument can photograph radio-communications and compare the qualities of various loud-speakers. It records the sounds that produce shell-shock. In photographs of the human voice it may be used as an aid to teach singing.

In recent experiments made by the Canadian Government to determine the most efficient type of fog-horn, the Phonodeik was used to pho-

tograph the sounds, which could then be analyzed.

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Professor Charles Elwood Mendenhall of the University of Wisconsin had for his subject "Electronic Phenomena at the Surface of Metals." The speaker comes from a family learned in physical science, his father, the late Professor Thomas C. Mendenhall, having been distinguished for his original work in regard to terrestrial gravity, atmospheric electricity, the solar spectra, seismology, and other branches of physics, throughout a long and honorable career. The son is a worthy successor. His address had to do with the influence of metallic surfaces on the nature of rays produced by electric bombardment. Stable conditions are only reached after a long continued heating of the electrode, and he concluded that the nature of the surface as well as that of occluded gases affect the nature of secondary rays, and that anomalies in photoelectric effects are due to the same causes.

In the photoelectric effect he found that as gas is removed from the tube, shorter and shorter waves are needed to produce it.

Platinum was chiefly studied. With the exception of one very short time he was able to get consistent results with a mercury arc, which is contrary to Swann's experience in Chicago, in which it was necessary to resort to Lyman's rays to get results in very high vacua.

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We have already spoken of the famous Braggs, father and son. Both are Nobel prize winners for their revelations about crystals. The former spent his early manhood in Australia as Professor of Physics at Adelaide University, and now occupies the chair formerly filled by Sir Humphrey Davy, Michael Faraday, and a whole line of England's great scientists as Head of the Royal Institution. His address concluded the Thursday morning session in Room 214 of the Engineering Building.

A most graceful and finished speaker, he had for his theme "The Carbon Atom in Crystalline Structure." He said that we have learned more in the last few years about the structure of the atoms of elements and that of molecules into which the atoms group themselves, than during ten thousand years preceding. This has been due to the X-ray, which has waves or

impulses 10,000 times shorter than those of light, and which therefore penetrate opaque solids and reveal what has heretofore been hidden from us. X-rays reflected from the interior of solids show us their crystalline structure and the connection and arrangement of the atoms which compose the crystals.

When a professor tells his class that the diamond and the black greasy graphite are absolutely the same; that both are composed of atoms of carbon and nothing else, it is easy to show, but hard to explain. But by making first models of carbon atoms by means of peas and toothpicks, which is not difficult, and then models of those same atoms grouped together to form a diamond with its crystalline structure and planes of cleavage, and, third, the graphite molecules built up in layers of atoms formed in six-membered rings, one series above the other, the student sees for himself. He recognizes immediately why light is reflected from the crystal planes of the gem, and why the other is so slippery, because its molecules, being in layers, slide, one over the other, readily. Sir William told of various fats that he had examined by reflected X-rays showing that they

consisted of 30 or more carbon atoms arranged in a snaky series with an acid head containing two carbon atoms. Then when a drop of the fat is squeezed between two plates, the fat molecules arrange themselves in perpendicular layers, half of them upright and the others upside down. Thus one molecule layer sticks to one surface, and the other to the other surface, and they slide over one another with but slight friction. They are so similar in structure as to run smoothly under this arrangement. This is what makes grease greasy.

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In Lecture Room 226 of the Engineering Building the first paper of the session was that of Dr. Irving Langmuir on "Electric Discharges in Gas at Low Pressures." Among the groups of remarkable men engaged in research in the great laboratory of the General Electric Co. at Schenectady, N. Y., he is one of the foremost. His contributions to the better understanding of nature have been many and important. It was he who showed us how oils and fats spread themselves on surfaces symmetrically with the OH end of the molecule at the bottom, producing films on water, for instance,

down to one molecule in thickness,—which gave Sir William Bragg the lead to his own observation as to why grease is greasy. He gave us the nitrogen and argon electric lamps, and his work in the development of Gilbert N. Lewis's "cubical atoms" which led to the Lewis-Langmuir Postulates as to Atomic Structures has been masterful and has made him world famous.

The present paper suggests a partial explanation of ball lightning if such a phenomenon ever does take place. He said that in connection with a detailed study of electric discharges in argon, he and his associates C. G. Found and A. F. Ditmer had observed some phenomena of remarkable beauty which may prove to be of theoretical interest. It is a new type of electric discharge, a streamer discharge.

A tungsten filament of 0.5 mm. diameter was mounted at one end of a pyrex glass bulb 10 cm. diam. and 15 cm. long, with axis horizontal. Rising vertically from this was a tube 3 cm. diam. and 50 cm. long, with a disc-shaped anode at its upper end. The tube is exhausted for an hour at 450°C., the electrodes are freed from gas by induction heating and the tube

then filled with very pure argon at a pressure of not over 2 to 4 mm. of mercury. The cathode is heated to about 2500°K, and + 250 volts is applied to the anode through a resistance. By approaching one terminal of a high frequency coil to the middle of the glass tube, an arc of about one ampere is started through the tube, and the voltage difference between anode and cathode falls to about 25 volts.

The arc then fills the tube with an uniform pale reddish glow (argon spectrum) and a transverse magnetic field from a hand horseshoe magnet, with poles 4 cm. apart, has practically no effect on the appearance of the arc.

Now by opening the cathode heating circuit for one half second, allowing the current to return immediately to its former value, the *streamer discharge* may be started. The cathode temperature is thus momentarily lowered, and by decrease of the electron emission, the voltage across the arc rises from 25 to 100 volts or more, for perhaps a second. The cathode drop thus established sputters tungsten from the cathode in an amount estimated at 10^{-6} to 10^{-7} grammes.

This slight dose of tungsten vapor has a

profound effect on the arc. There are at first brilliant blue flashes of light from the lower end of the tube, showing the tungsten spark spectrum. Simultaneously the arc begins to detach itself from the glass walls, starting at the lower end and gradually, in 5 to 15 seconds, extending up to the anode.

After about 30 seconds the blue tungsten spectrum disappears and the arc quiets down but remains wholly detached from the walls. At first the arc is 1 to 1½ cm. in diameter, and is bounded by a sharply defined luminous skin which emits a dull yellowish light showing a continuous spectrum. The interior of the arc is reddish (argon spectrum) but is separated from the yellow skin by a dark space 1 to 2 mm. thick. Sometimes just inside this dark region there is a transient bluish skin of considerable brilliancy which seems to show a mixture of continuous spectrum with that of the tungsten. Then, after perhaps one minute, the yellow skin disappears and the arc has increased so much in cross section that it seems at first as if it had returned to the original condition. But the arc is now very sensitive, even to weak magnetic fields. When the horseshoe magnet

is brought to within 10 to 15 cm. of the tube, producing a transverse field, the arc is deflected to one side of the tube, it is packed up against the wall of the tube, and at the same time the yellow skin reappears on the side of the arc opposite to that which is in contact with the wall.

On bringing the magnet closer the yellow skin becomes thinner and more brilliant, and then it begins in a remarkable way to exhibit many characteristics of a liquid surface. It is strikingly like that of the surface dripping from the under side of a wet board. Droplets of golden liquid fire form slowly, move irregularly parallel to the direction of the surface, and then break away and fall, as little spheres of light in a direction perpendicular to the surface.

By regulating the intensity of the magnetic field these droplets or globules, ranging from a few tenths mm. up to 5 or 6 mm. in diameter, can be made to form slowly and to detach themselves singly from the skin of the arc. Usually they move all the way across the arc and disappear when they reach the opposite boundary close to the glass wall. They may be made to move upwards or downwards, in the arc

parallel to its axis for distances of 5 to 10 cm. The light emitted from the globules is nearly white, and of dazzling brilliancy compared with that from the yellow skin of the arc.

The globules have been observed to move slowly so that their motions could be easily followed by the unaided eye. More often they move at velocities of 10 to 30 cm. a second, and then appear as glowing lines or filament streamers. As the field is increased the streamers remain in evidence.

By superimposing an alternating component on the direct current fed to the anode, or by heating the cathode by alternating current, the streamers or individual globules move in sinusoidal paths which reproduce accurately the wave shape of the current, even at frequencies up to 1000 cycles. Sometimes the arc discharge itself oscillates at about 1000 cycles, and the globules then increase and decrease periodically in brilliancy. By "stroking" the tube with the magnet the tungsten responsible for the streamer discharge can be concentrated at either end of the tube.

These effects persist for hours, as long as the arc current is maintained at about 1 ampere,

without the need of replenishing the tungsten vapor.

If the arc is allowed to remain out, say 40 seconds, practically all the effects due to tungsten vapor disappear, and to renew the streamer effect one must go back to the sputtering tungsten.

Similar effects are obtained by sputtering molybdenum, tantalum or carbon in the arc, but the phenomena obtained with tungsten are both more persistent and more striking.

Further observations with an outline of the underlying theory were given, and will be printed in full later. The general conclusion is that these glowing detached globules show characteristics in many respects similar to those described as ball lightning, and that if there is such a phenomenon as ball lightning it may be ascribed to causes indicated by these experiments, namely, the presence of highly ionized gas, recombination of ions on catalytically acting solid particles which are held within the ball by their charges and the electric field at the surface of the ball.

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Professor Charles Fabry of the University of Paris, and head of the Institute of Optics founded by the French Government, told of "The Spectroscope, Past and Present," as to which he is a leading authority.

He gave an historical resumé of this remarkable instrument which, in his own words, "speaks a language all its own," in the light of analysis of substances. He told of the great work achieved in determining the constituent parts of the stars, and again, in its later development as an aid in revealing the secrets of the structure of atoms. He stated that we are now on the eve of startling discoveries by this same means.

We regret that Dr. Fabry's interesting paper has not yet been received for publication in full, and that it has not been possible to secure a more complete digest of it from those in his audience.

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Mr. F. W. Peek, of the Pittsfield Laboratory of the General Electric Co., told of "Lightning." It was Mr. Peek who developed artificial lightning in the high voltage laboratory in order to study its ways. The great feature in regard

to it is the time factor: when energy enough to drive a good sized motor car 5 miles is concentrated into a flash of only 2 or 3 millionths of a second in duration, it carries almost everything before it. It will all happen, so to speak, at once. If the same measure of energy, which lasts only this minute fraction of a second, were to continue indefinitely—say, for half an hour —we should have millions of horse-power units developed. The study of lightning is called for, because it gives us the movements of electrons in their struggle to establish equilibrium, and from it we learn of various activities of currents of electricity.

This artificial lightning was achieved in the laboratory with some 2,000,000 volts, whereas in nature the voltage runs up to 100,000,000.

A lightning-rod will protect an area with a radius of four times its length, and if it reaches up to within 1/40 the height of the cloud which contains the electric charge, it will release the lightning. In other words, the lightning will then score 100% of hits. An ordinary sized man standing upright under such a cloud will be struck 15 times out of the 100 impulses that occur, whereas, if he lies down flat, the

chance of his being struck is only one in a hundred. The moral is to take your lightning flat.

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Professor A. E. Kennelly of Harvard University and the Massachusetts Institute of Technology followed Mr. Peek with a paper on "The Measurement of Acoustic Impedance by the Aid of the Telephone Receiver." Professor Kennelly was born in Bombay, was at school in London at the age of ten, and at fifteen was an electrician to the Eastern Telegraph Co. there. He took to electricity from the beginning. At twenty-five he was principal electrical assistant to Thomas A. Edison, and eight years later he set up as consulting electrical engineer in Philadelphia. In 1902 Harvard called him as Professor of Electrical Engineering, and as Tech soon wanted him too they divide his time between them. A member of various learned bodies, he has been the recipient of many honors.

He described a method of measuring the acoustic impedance of solids or gases in the form of discs or cylinders to the passage of plane waves of sound. He outlined the analogies be-

tween an electric line conductor and an acoustic tube conductor. Then followed a description of his sound measurements.

It is an effort to discover the underlying principles of sound along lines of work already done in electricity, and to bring our knowledge of this field of acoustics into better understanding.

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In the hall of the University of Pennsylvania Museum Dr. Samuel Insull of Chicago presided over another series of lectures.

Dr. Edwin Wilbur Rice, Jr., was the first speaker. He was born at La Crosse, Wisconsin, but attended the Philadelphia Central High School, which almost makes him an alumnus of Franklin Institute. Then he went to Harvard, and thence to Dr. Elihu Thomson at Lynn, as technical director of the Thomson-Houston Works, now part of the General Electric Co. From 1894 to 1913 he served as Vice-President of the latter organization, and from that date until two years ago he was its President. He is now Honorary Chairman of its board.

His subject was "The Field of Research in Industrial Institutions," and he speaks with

peculiar authority on it because the General Electric Co., like the Telephone Co., the Eastman Kodak Co., and all-too-few other concerns in America that are engaged in work that is based on scientific principles and scientific understanding, invites men of science to participate in its councils.

Research may not be successfully conducted by the mere fiat of the authorities of a corporation. "I sometimes wonder," exclaimed the speaker, "whether the success of science will not prove its undoing. We are too familiar with its wonders, and familiarity breeds contempt. Let us rather approach science in a spirit of humility and endeavor, and let us carry that spirit still farther to a consideration of man's relationship to man, so that we may seek out the highest public good." To the outsider, he explained, research often appears uninteresting, because the outsider sees the same experiment repeated with but minute variations, sometimes over a space of ten or twelve years. But to the man of understanding this work is of signal interest, while his curiosity is constantly piqued.

The returns are sometimes immense, and they are always of importance. Even negative re-

sults serve as warnings what to avoid. But as an example of the general value of this work when carried to completion and without disturbance, he cited the tungsten lamp which alone saves the nation a billion dollars annually in the cost of electric lighting.

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Dr. Ralph Modjeski is well known to men of affairs for his successful work as an engineer. His mother, Mme. Modjeska, entranced the older generation of Americans by her subtle, artistic, and scholarly acting, and her son, though born in Poland, grew up and received his education in the United States. The artistry which is his inheritance touches with grace the scientific presentment of his distinguished work in his chosen calling.

"Unusual Problems Encountered in the Design and Construction of Large Bridges" was his theme. The Delaware River bridge, it seems, offered the most trying problem in his career as a builder of bridges. At first five different locations were considered, having reference to real estate values, traffic conditions on both sides of the stream, the physical aspects of the terrain, and the existing capacity of

ferries. The foundations had to be laid on bedrock, and bedrock was down 160 feet,—too great a depth to permit the use of pneumatic caissons. So they made a 30-foot tube of concrete on the surface, excavated around and under it until it sank, and then they poured other concrete masses atop of it. It was all heavily reinforced with steel bars to carry the immense strain, and they continued digging and digging around and underneath it until the great anchorage gradually forced its path downward and finally rested firmly on bedrock.

To reconstruct existing bridges without disturbing traffic is another problem encountered in this kind of work.

New alloy steels, said the speaker, are of great value to the engineer, their extraordinary strength permitting the design of greater span, while yet affording a higher degree of safety than in the past. On account of these new qualities of steel he predicts radical improvements in the bridge-building of the future.

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Sir Charles Algernon Parsons is known the world over as the inventor of the steam turbine. He spoke of "Steam Turbines on Land and

Sea," and told of the present tendency to reach higher temperature ranges and greater pressures. He dwelt confidently on the attainment of 2,000 lbs. boiler pressure, saying that there is a 1,500 lb. boiler in England now, and one operating at 1,200 in the United States. He went into the details, physical, chemical and mechanical, which have to be met, and expressed the conviction that although 750° Fahr. is the maximum temperature for use in turbines, an efficiency is available equal to that of internal combustion engines. In point of economy of operation the turbine is the equal of other types and it is also more economical to install.

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Dr. W. L. R. Emmet gave a description of the Emmet Mercury-Vapor Process which is proposed as an improvement over the steam boiler and engine for developing power. Dr. Emmet is a well-known engineer who was born at Pelham, N. Y., and graduated from the U. S. Naval Academy in 1881. He served as cadet-midshipman until 1883, when he left the navy, re-entering it again for the period of the Spanish-American War. His principal industrial activities have been with the Sprague Elec-

tric Railway & Motor Co. and with the General Electric Company. He designed and directed the development of the Curtis turbine for the General Electric Company, and was the first serious promoter of electric ship propulsion. He invented several types of transformers, several types of insulation of alternators, an oil switch now in general use, and other devices.

The principle involved in the Mercury Vapor boiler was first suggested to him by Charles S. Bradley, who has been a pioneer in many fields. Mr. Bradley did not propose the use of mercury, but rather of some other substance of sufficiently high boiling point and he took out a patent involving the general principle of such an application. It consists in boiling a substance having a high boiling point and using the vapor so produced to drive one or more special turbines. The vapor then continues to do useful work, exhausting into a surface condenser where its latent heat is used to make steam at a pressure sufficient to drive a second series of turbines. The condensed high-boiling liquid is then carried back to the boiler, preferably by gravity. The process affords means by which the temperature ranges practicable

with steam are greatly increased, under conditions which afford large gains in efficiency of the conversion of the heat energy of fuel into work.

The possibilities of the process were first explained by Dr. Emmet in 1913, and two years later work was begun in Schenectady to build a 1500 kw. mercury turbine. From that time on the development has been continuous. After much consideration it was concluded that mercury, despite its high cost, poisonous quality, and its tendency to oxidize, might be applied to the purpose and was the best material available.

The boiling conditions of mercury are peculiar and very different from those of water. The metal does not wet the surfaces, and there is a wide difference of pressure at different depths. Its poisonous nature and its cost make it necessary that all leakages be avoided and the construction must be such that the mercury circulates from the boiler through the turbine (or series of turbines) and through the condenser, back to the boiler again very rapidly.

The boiling of mercury might theoretically be accomplished at any practicable temperature

and pressure, and experience has indicated that higher temperatures may be availed of than those that have been considered. The condensation of the mercury and the making of steam can also occur at any point in the descending temperature scale which gives a practicable mercury vacuum. The final termination of the steam action, on the other hand, must be at the temperature of the cooling source: that of condensing water.

For example, let us assume a boiling temperature of 884° Fahr. corresponding to 70 lbs. pressure in the mercury boiler. As a temperature for condensing mercury let us assume 438° Fahr., which corresponds to a mercury vacuum of 28 1/2 inches, which is suited, with a temperature difference in the condenser of 21° Fahr., to making steam at 285 lbs. gage pressure.

Details of the design are available for those who wish to follow it up. Our purpose is merely to follow the speaker in telling some things about it. A test plant has been put up at one of the stations of the Hartford Electric Light Company and is doing service. Leakage is effectively avoided and in ten years of experi-

mentation they have experienced no case of poisoning. In this respect they have, of course, exercised great care. The economies as figured out by Dr. Emmet are no less than surprising. Taking three large steam plants, among the best in the country, and comparing the gain in output which would have resulted if the same fuel had been burned under mercury boilers with the same auxiliary and flue gas conditions, and assuming that the mercury turbines with generators were 70% efficient and that a mercury pressure of 70 lbs. gage were used, he computed a gain of respectively 65, 58 and 51% for the three plants.

In regard to the mercury supply he believes that a maintained price of about $2. per lb. (say double the present price) would induce the working of lean ores and would call forth even from known sources in the United States, enough mercury to correspond in plant capacity to the largest yearly output of General Electric turbines.

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On Thursday afternoon there was a general exodus to the Philadelphia Country Club, and here in the beautiful grounds, the mellow glow

of the September sunshine repeated itself in the cordial welcome given to the guests by the ladies and gentlemen who represent the social life of a city famed for hospitality. Here, as one of the newspapers put it, the discussion turned from photostatics and tensile strength to golf, and from ionized solutions to the cheering cup of tea. Sir William Bragg forgot the carbon atom as he led off on the links; the ladies found Sir Ernest Rutherford radioactive in conversation, and it was reported that several Indian arrowheads were found in the intervals of social amenities by that zealous collector, Dr. Whitney. All in all this was voted one of the completely successful sessions of the centenary meeting.

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In the evening an open meeting was held in the Hall of the University Museum, ex-Governor Sproul presiding, and the address was given by Sir Ernest Rutherford.

One of the six Nobel prize winners present, Sir Ernest also received this year's Franklin Medal for his contributions to human knowledge. By birth a New Zealander, he studied, first at home, then at Cambridge under Sir

Joseph J. Thomson, afterward becoming Professor of Physics at McGill University, Montreal. From this post he was summoned to Manchester, thence to his alma mater, Cambridge, where, with his old master and some of his own pupils, they have brought the Cavendish laboratory in Caius College to supreme eminence. Among the scientific leaders that owe their training to this distinguished group are Aston and Bohr. Nor must the lamented Mosely's name be omitted. Sir Ernest's outstanding work has been in radioactivity, and in relation to the structure of atoms. The hall was crowded; a considerable number of the leading scientific men of Europe and America who were a bit late in arriving stood at diligent attention along the walls during the entire address.

He began by saying that the idea that elements were made up of discrete particles called atoms started early in the nineteenth century, when it was held that they were indivisible, and could not be broken up by chemical or physical means at hand. But a great change was effected by the discovery of radioactivity. This taught that the atoms of radioactive elements are in a per-

petual state of change, and that of the 80 odd elements known to us, or of the 92 possible elements we recognize, over thirty are so affected. That is, that they are in a constant process of throwing off alpha, beta and gamma rays which are respectively the nuclei of helium atoms, electrons and rays similar to X-rays, but of conspicuously short wave length.

Within the past decade we have come to fairly definite ideas as to the gross constitution of atoms. Every feature still lacks proof, but there is ample evidence to support the theories propounded. We seem to be getting nearer the truth about the atom. We must first bear in mind that we are dealing with entities incredibly minute. If we enquire how many atoms there are in a cubic centimeter of air—a mere thimbleful—in which the atoms are by no means crowded, we reach numbers that are overwhelming. That little thimbleful contains so many atoms that if all the thousand million people on the globe were set to counting them at the rate of three to a second, working day and night, it would take them ten thousand years to complete the task.

He explained how each atom is made up of a

nucleus at the center which consists of the positive charges, while electrons, which are negative charges, revolve around this or are somehow held in leash by it. But this nucleus, although it is responsible for the major part of the atom's weight, is but a tiny fraction of its volume, so that while atoms are small, their nuclei are relatively far smaller. Nevertheless they are worlds in themselves, miniature worlds.

Thus the lightest of all, the hydrogen atom, consists apparently of a single positive charge as its nucleus with the accompanying electron held at some distance from it. That is No. 1 of the series of elements. The last, because the heaviest, is uranium, No. 92, so recorded because that is the number of its free positive charges (plus something, evidently of the substance of hydrogen and helium atoms), with, of course, 92 electrons arranged or revolving about the nucleus.

In association with his Cambridge colleagues Sir Ernest succeeded in knocking out of the nuclei of various of the lighter atoms simple positive charges which appear to be the nuclei of hydrogen atoms. This was done by means of a bombardment with alpha particles from

radium C. Atoms of some 15 different elements were thus disintegrated. But what is the all-powerful force or manifestation of energy that holds the component parts of the atom together? We do not know. And with that untiring curiosity, at once intelligent and learned, that is the key to man's conquest of nature, Sir Ernest is working away to find out. We have only space for brief notes of his illuminating address. From these we note his observation, however, that the relatively small mass or weight of the electron—only 1/1850 of that of the proton or positive charge—is entirely associated with its electrical structure, so that it may be regarded as "a disembodied atom of negative electricity." We know that an electron in motion, in addition to possessing an electric field, generates a magnetic field around it and energy in the magnetic form is stored with the medium and moves with it. This gives the electron an apparent or electrical mass which, while nearly constant for slow motion, increases rapidly as the velocity approaches that of light.

This also hints at the interchangeability of energy and matter.

If from an atom of hydrogen we remove its single electron, there remains the positively charged hydrogen ion, or, as we say, a single positive charge or proton. Why, then, has this entity whose volume is so much smaller than that of the electron 1850 times its mass or weight? Electrical theory shows us that the mass of a given charge of electricity increases with its concentration, and so the mass of the hydrogen nucleus would be accounted for by its smaller size than that of the electron.

Some ten years ago we set great store on discovering a way to disintegrate atoms and thus liberate the fund of energy that holds them as units. The intervening ten years of study have persuaded Sir Ernest that this as a source of energy to replace coal or water power is unlikely. He thinks it would take more energy to release it than we should get out of it. He told, however, of the vast energy released when hydrogen is apparently consolidated to helium: in the birth of an element rather than by its destruction. This is because hydrogen nuclei which are required to make up the nucleus of a helium atom lose mass in the process, and it

appears that here again the excess mass is delivered as energy.

The speaker was engagingly frank in acknowledging what he does not know or understand: as, for instance, the ether of space and the real structure of the nuclei of atoms.

He paid high compliment to two American chemists for their contributions to the study of the structure of the atom: Professor Gilbert N. Lewis of the University of California and Dr. Irving Langmuir of the General Electric Laboratory at Schenectady.

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Friday morning witnessed the unveiling of the memorial tablet to Henry Welchman Bartol in the hall of the Bartol Research Foundation Building, 127 North 19th Street.

Mr. C. C. Tutwiler, Vice-President of the Institute, presided, and delivered the eulogy on the giver of this great work of beneficence. He stressed the fact that Mr. Bartol, although a business man and not himself a scientist, had nevertheless the scientific vision to sense the opportunity for an enduring service to humanity through the specialized work of a small

group of men of the highest training and proved fitness for the task.

Then a young girl of thirteen, Teresa Bartol Dally, grandniece of the founder, pretty, but looking grave and learned in view of her responsibility, pulled a cord, releasing the purple veiling and disclosing the memorial.

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Dr. Arthur Dehon Little is one of the best-known chemists in the United States. He has a great research laboratory at Cambridge, Mass., has been President of the American Chemical Society and of the Institute of Chemical Engineers, and probably has helped a wider variety of industries than any other consulting chemist in the country. Whenever he speaks he has something to say. His address, "The Fifth Estate," delivered in the hall of the Academy of Science, delighted the large audience gathered to hear him. The paper in full has been printed in the *Journal* of the Institute and in the December, 1924, number of the *Atlantic Monthly*.

The career of Benjamin Franklin refutes the charge that the man of science is temperamentally unfitted for the practical business of life,

said the speaker. The "Fifth Estate" is added to the four designated by Edmund Burke: "the Lords Spiritual, the Lords Temporal, the Commons, and the Fourth, which is that of the man of the Press." This Fifth Estate, according to Dr. Little, comprises those who have the simplicity to wonder, the power to generalize, the capacity to apply. In a word, it consists of thinkers, workers, expounders, and practitioners, a company on which the world is absolutely dependent for the preservation and advancement of that organized knowledge we call science. "It is this company that brings the power and the fruits of knowledge to the multitude who are content to go through life without thinking, without questioning; who accept fire, the hatching of an egg, the attraction of a feather by a bit of amber, and the stars in their courses, as a fish accepts the ocean."

In all the world, he declared, there are not more than 100,000 persons whose creative effort is responsible for the advancement of science. These chosen minds come principally from upper and middle classes, and three quarters of their number depend on universities for their maintenance. So few of those who

study have initiative,—or, rather, so many who profess to study either do not or cannot apply what they learn to constructive uses—that the cost of a single man competent to advance science is estimated at no less than $500,000, his value being far beyond that sum. "And yet," he quoted Wiggam, "only genius can create science, though the humblest may imbibe its spirit. The humblest may learn to face the truth."

With all praise for the modesty of scientific thought the speaker advocated a reasonable militancy in this domain, emphasizing the crying need for at least one Huxley to every William Jennings Bryan!

This Fifth Estate, with a world population no larger than that of Nebraska, has "recast civilization through its study and application of the great fundamental facts of nature and the laws that govern nature's operation. It has opened out the heavens beyond imagination, weighed remote suns and analyzed the light that left them before the dawn of history. It has moved the earth from the centre of the universe to its proper place within the cosmos.

. . .

"Because of this new breadth of vision, this lifting of the corner of the veil, this new insight into the hidden meaning of things about us, the mind of man, cramped for ages, and bound by superstition, is emerging into freedom at last.

"Man brought nothing into this world, and for long and painful ages he added little to that nothing. To those who would have us believe that all wealth is the product of labor, the Fifth Estate replies: Wealth is the product of brains, and labor is productive only as it is guided by intelligence.

"It is not labor, but the trained intelligence of the Fifth Estate that has endowed man with his present control of stupendous power."

Dr. Little further noted how slender is the recompense, but how delectable the life enjoyed by this Fifth Estate in the Kingdom of the Mind. His address was an earnest plea for the use of scientific intelligence in the control of affairs.

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"Stimulation of Research and Invention" was the title of the address delivered at the open meeting in the Academy of Natural Science by Professor D. S. Jacobus of New York, follow-

ing Dr. Little. Dr. Jacobus is professor of experimental engineering at the Stevens Institute, head of its Carnegie Laboratory of Engineering and conducts a large consulting practice. He is a leading authority on steam engineering, and has carried on and directed research for many years.

Discovery, or the vision of a new thing, usually comes from a single individual. He may or may not be engaged in research; but the former is the more likely. He is addicted to finding out what has been done, and trying out what may be done. Moments of discovery are very precious, and they occur more readily, as a rule, under encouragement. The speaker emphasized the important part played in this respect by the Franklin Institute, by inspiring and encouraging the individual to put forth scientific effort, and the happy results that have followed. He also noted the extension of the golden opportunities made possible by the Bartol Foundation.

On the other hand it is sometimes difficult to trace an invention to its actual source. In coordinated research the solution of a great problem is sometimes made up of a number of con-

tributions of several workers. This situation arises occasionally in industrial corporations, and was of frequent occurrence during the war when the tensest efforts were made to achieve efficiency in specific lines of defense and offense.

It is far from a simple matter to administer research funds with constant wisdom and the avoidance of error, said the speaker, whose concluding remarks were devoted chiefly to the development of general principles and rules under which, in his opinion, the Bartol Foundation might be most effectively conducted.

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Professor W. F. G. Swann of Yale University spoke in the Harrison Chemical Laboratory, Friday morning, on "The Origin of the Earth's Electric and Magnetic Phenomena." Dr. Swann comes rightly by his scholarship, his father before him having been eminent as a physicist, and one of the leaders of the development of the electric light in England.

His paper was still missing at the time of going to press and no abstract of it was obtainable. It will be printed in full by the Institute later.

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Professor Pieter Zeeman of the University of Amsterdam is famous for his researches in the field of physics, more particularly in magnetism, and he is widely known as the discoverer of the "Zeeman Effect." The subject of his paper was "Radiating Atoms in Magnetic Fields."

At the present writing it is in course of final preparation for printing and therefore not available. It will be printed in full when it is received.

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The papers of Professor John Sealy Edward Townsend, F.R.S., of Oxford University, on "Motion of Electrons in Gases" and of Dr. J. Slepian of the Westinghouse Electric and Manufacturing Co. on "Electric Discharges between High Resistance Electrons" are still in preparation for final printing, and abstracts of them are not yet available.

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After delivering his address on the Fifth Estate at the Academy of Natural Sciences, Dr. Little presided over a meeting in Room 16 of the Engineering Building. The first speaker, Dr. Charles L. Reese, told of "Twenty-five

Years' Progress in Explosives." And this title he qualified by restricting his remarks to progress in the United States.

Dr. Reese stated that black powder, the forerunner of all modern explosives, had undergone little or no change in composition for many years except in the substitution of sodium nitrate in blasting powders in this country. Few changes have been made in the manufacture of this material except in modifications in the design and construction of apparatus and machinery.

In 1900, dyamite, to the layman and most professors of chemistry, was a mixture of nitroglycerine and infusorial earth, but the latter inert material has been replaced for many years by a properly balanced mixture of wood pulp and sodium nitrate, as it was found that the use of an inert absorbent was extremely wasteful. For many years after this, American manufacturers of active base dynamites found it necessary to color their dynamites red for the Mexican trade, which was accustomed to the naturally red "Guhr" dynamites sold by European manufacturers.

The characteristics of the three principal

types of dynamite which are manufactured in the present day were also explained.

In 1923 the Bureau of Explosives showed that 530,000,000 pounds of explosives were produced and distributed in this country, of which 330,000,000 pounds were in the form of dynamite, and consequently 100,000,000 pounds of nitroglycerine were produced during the year for this purpose. As the production of so great a quantity of nitroglycerine consumed large amounts of glycerine, Dr. Reese showed what scientific steps had been taken to improve the yields of nitroglycerine from glycerine. He also showed how difficulties had been overcome in connection with the separation of nitroglycerine from the waste acid. Ordinary nitroglycerine freezes at about 55° F., and owing to the danger of handling and thawing frozen dynamite, which was the common practice until recent years, methods had to be sought for producing a dynamite which would be difficult to freeze. Dr. Reese describes the experiments which were tried in an effort to achieve this result, which finally led to the perfection of an explosive which was practically non-freezable. Nearly

all of the dynamites made in this country to-day may be used without the necessity of thawing.

Such materials as trinitrotoluene, sugar, etc., were used in connection with glycerine to lower the freezing point and finally the non-freezing dynamites were obtained by the use of tetra-nitro-di-glycerine in conjunction with nitroglycerine as the explosive base for this material. Since many men in times gone by have lost their lives in thawing and handling frozen dynamite, the introduction of non-freezing dynamite is a great boon to the users of this dangerous material.

Dr. Reese has also described and explained the development of the so-called "permissible" explosives for use in gaseous and dusty coal mines, which has resulted in preventing the death of many coal miners from accidents caused by the use of black powder. He described the development of many classes of explosives of this character. He said: "I have made inquiry of the Bureau of Mines as to whether their statistics would show whether any explosions of gas and coal dust could be attributed to permissible explosives, and I quote their reply: 'Referring to your letter of July

31st, the Bureau of Mines has not published any statistics of mine explosions classified according to the kind of explosives used. However, the Bureau's record of mine disasters covers a large number of explosions of gas and coal dust, and to date no such disaster has been found to have been caused by the use of permissible explosives.' This is certainly a most gratifying piece of information for those who have been expending their energy along these important humanitarian lines, not only in the Bureau of Mines, but also among the coöperating manufacturers, and it should spur the miners on to the extended use of this class of explosives."

He also discussed the importance of finding substitutes for nitroglycerine owing to the annual increase in the use of high explosives in which nitroglycerine is the principal explosive ingredient, and since glycerine is a by-product of the soap and candle industry, it was felt that sooner or later there would be a shortage of the material and consequently substitutes for glycerine had to be sought. Among the materials which have been used as substitutes for nitroglycerine are ammonium nitrate, sugar,

trinitrotoluene, nitro-starch and other more complex organic materials.

He explained why the Government had to abandon the use of wet gun-cotton blocks in submarine mines owing to the difficulty in exploding them and the consequent substitution of trinitrotoluene for this material in submarine mines.

Owing to the shortage of trinitrotoluene, due to the World War in 1914, means were devised for manufacturing materials from benzene and xylene and also a new explosive was developed known as trinitroxylene, large quantities of which were manufactured for the Navy.

At the close of the World War, there were in the hands of the U. S. Government approximately the following amounts of explosives:

330,900 lbs. Fulminate of Mercury

1,720,000 lbs. Nitrostarch

60,500,000 lbs. Ammonium Nitrate

100,000,000 lbs. T.N.T.

6,500,000 lbs. Ammonium Picrate

20,000,000 lbs. to 25,000,000 lbs. Picric Acid

200,000,000 lbs. Smokeless Powder.

The question arose as to what to do with

this enormous amount of explosive material. It was even seriously proposed to dump the picric acid into the ocean, and this disposition was made of a small quantity. Dr. Reese opposed this wasteful destruction of valuable property, believing that it could all be eventually used in some way, and to-day most of this excess war material has been used or is being used in the manufacture of explosives for peace-time uses. He pointed out that the largest contract ever awarded for explosives has just been made by the U. S. Government for 100,000,000 lbs. of an explosive to be known as "Pyrotol," which involves the use of excess stocks of smokeless powder in its manufacture. This explosive is to be used purely for peace-time purposes such as distribution to farmers, etc.

In his address Dr. Reese was able only to summarize in a very general way some of the more important results of the work which has been done at the Eastern Laboratory of the duPont Company in connection with the development of high explosives. In closing, he said: "Our efforts have been to advance the art and to reduce the danger, not only in the manufacture, but also in the handling, transportation

and use of a material intended to do work by explosion, and thus reduce accidents to humanity to the minimum in its employment."

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Professor Frederick G. Donnan of University College, London, where he succeeded the late Sir William Ramsay, was the next speaker. Before quoting his remarks it might be well to ask the reader to name the greatest man in science that America has produced during the last hundred years. One who ranks with Sir Isaac Newton. Henry Adams said that after Benjamin Franklin he was our greatest man of science. The answer is Josiah Willard Gibbs, Professor of Mathematics at Yale, who died in 1903. He ranks, as Dr. Donnan said, with the highest. This quiet unassuming man was recognized first in Europe, then here. He was the herald of physical chemistry, for he created the new science by the working union of physics with chemistry. His address before the Connecticut Academy of Sciences in which he introduced the Phase Rule was one of the mightiest works of human genius. Like Newton, Lagrange, Hamilton, Avogardro, Robert Boyle, Gibbs has, by sheer force of the powers

of his mind, produced a generalized statement of scientific law which marks an epoch in its advancement.

Professor Donnan told how during the war it was necessary to make ammonium nitrate in enormous quantities for the British High Munitions control. The chemist solved this problem by the use of Gibbs' thermodynamic formula. He gave Gibbs credit for the lead in what has developed into the so-called Donnan Equilibrium in colloid chemistry, and on which the late Professor Jacques Loeb based his work on proteins and their behavior. There is not a great chemical or metallurgical industry to-day that does not depend for its economical and scientifically controlled operations on the great contribution of Josiah Willard Gibbs. The speaker concluded with an exhaustive mathematical demonstration of Gibbs' work.

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By the time Professor Donnan had concluded it was about two o'clock. The only slip in all the arrangements was that so much was crowded into the last day's session that Dr. Edgar Fahs Smith, Provost Emeritus of the University of Pennsylvania, refused to keep the

audience from their lunch, and so his address on "Early Science in Philadelphia" was missed from the occasion,—missed with deep regret, for many of those present would at any time gladly forego a meal in order to enjoy the delectable feast provided by an address from Dr. Smith.

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Professor Alexander E. Outerbridge, Jr., of the University of Pennsylvania was in charge at a metallurgical meeting in Room 226 of the Engineering Building on Friday morning at 11.30.

The first speaker was Professor C. H. Mathewson of Yale University on "The Trend in Physical Metallurgy." He gave a history of what has been accomplished in modern times, leading back to Josiah Willard Gibbs and his far-famed Equilibrium of Heterogeneous Substances. From this was evolved the conventional graphical methods of expressing constitutional relationships in two or three component systems. A vast array of data has been made available in this connection,—and it is useful, albeit not comprehensive of all that we would know. The open road to greater results he be-

lieved to be along the lines of X-ray spectography, as developed by the Braggs, and from better understanding of atomic structures. The modern tendency he believed to be in the development of a theory of constitution of individual phases or phase elements which shall be susceptible to quantitative expression in defining the properties of these phases.

He gave an example of his own experience in connection with white gold, with his observations on its properties, and closed with a look ahead as to the practical utility of Physical Metallurgy.

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Dr. George L. Kelley is a Harvard man who is now research chemist for the Midvale branch of the Bethlehem Steel Corporation. His paper was on "The Restraint of Exaggerated Grain Growth in Critically Strained Metals." It is not yet in hand, but will be published later.

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Professor Bradley Stoughton of Lehigh University has within the past few years left active practice as an engineer to take a chair in an institution where his work is actively featured. His address concerned itself with the

"Magnetic Analysis of Steel," and in it he emphasized the need of magnetic methods and the importance to metallurgists of making themselves proficient in this phase of their work. Heretofore this has been left too much to the physicists who brought out significant data, the application of which, however, was not worked out. He mentioned many such applications that should enter into every-day practice. In Sweden the magnetic method is used exclusively for the determination of carbon in steel, the Royal Swedish Institution having awarded a gold medal to the inventor of the process. The General Electric Co. has been employing the method for the past two and a half years to determine the soundness of steel used in their turbine bucket disks. A large automobile concern uses it to determine the suitability of their master-gears and differentials. A chain company tests their case-hardened chains by it, and a manufacturer of roller bearings found that breakages in his wound-up strip steel could be absolutely avoided by this magnetic testing.

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Mr. T. D. Yensen, a research engineer for the Westinghouse Co., spoke on "The Magnetic

Properties of the 50% Ferro Nickel Alloy." The paper points out the value of ferro nickel alloys in general, describing the 50% alloy in particular. It shows how this may be annealed in such a way as to produce remarkably good magnetic properties. Comparison is made with the 78% Nickel Alloy, 4% silicon and pure iron.

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In Lecture Room 314 of the Engineering Building General George O. Squier presided, the session beginning at 11.30 A.M.

The only American Nobel prize winner present was Professor A. A. Michelson of the University of Chicago, whose experiments in regard to the velocity of light formed one of the foundations of Einstein's theory of relativity. His paper was entitled "The Results of a Preliminary Determination of the Velocity of Light." This summer (1924) he began a new series of determinations with a view to obtaining a greater accuracy than has heretofore been secured in measuring its velocity. He set up two stations in California, one at Mt. Wilson and the other, twenty-two miles distant, on Mt. San Antonio. He then induced the U. S. Coast and

Geodetic Survey to measure the distance between these two points, which they did to the exactness of one part in 500,000. At the precise starting-point on Mt. Wilson he set up a Sperry arc lamp, and at the terminal on the other mountain he placed an octagonal mirror which rotated at a predetermined rate of speed. The light was shot from Mt. Wilson, focused on the revolving mirror twenty-two miles away, which reflected it back to the starting-point. Then he measured the lag, which gave him the velocity. He believes this experiment to have been correct to within one part in 10,000, and his determination was 299,820 kilometers per second. By an improvement in the control of the rotating mirror he expects next year to get it correct to within one kilometer per second, or to about 1 in 300,000.

Somebody asked the lecturer why he should strive to be so meticulously accurate in his measurements, since we know of no greater velocity. To this he answered that if we can determine the length of a wave of light we shall have a unit of length that is universal, and if we can have its exact velocity we shall have a

universal unit of time. A practical value may be to provide an exact system of measuring distances, and in certain cases it may permit us to discard triangulation.

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Major General C. C. Williams concluded the series of lectures given under the chairmanship of General Squier on Friday morning with an address on "Modern Ordnance," a subject on which he is an authority, being chief of the Ordnance Department of the Army. It appears that since the great war marked changes have been made in the instruments of warfare. "From the long-familiar Springfield rifle to the most powerful defense guns and howitzers," he said, "sweeping changes have been made. There is a semi-automatic rifle that is in process of development, complete, except for the task of making it light enough. In place of the war-time machine-gun a 50-calibre weapon has been developed. John Browning has completed a new anti-aircraft machine gun that will supplant the older type. There is a new truck motor, far more complex, but also far more efficient than the bomb tossers used in the World War. Caterpillar tanks have been speeded up to

ten miles an hour, and the newer models are surrounded by turrets bristling with guns.

"The new 75 fieldpiece has a range of 15,000 yards against 9700 during the World War. The 155 mm. gun is succeeded by one of 105 mm., which is more easily moved, and has a range of 20,000 yards instead of but 12,000." He gave a complete review of the increased efficiency of ordnance designed since the war.

"The German Big Bertha dropped 183 shells into Paris and 120 outside the city. It killed and wounded 620 Parisians, and was an eight-inch piece shooting a shell that weighed 263 lbs."

CONVOCATION

On Friday afternoon at a special convocation held in College Hall, six participants in the centenary celebration received the honorary degree of Doctor of Science from the University of Pennsylvania.

After a brief speech of welcome, President Josiah H. Penniman, who presided, said: "It is particularly appropriate that the University founded by Benjamin Franklin should participate with the Institute in its centenary. The

University now puts its imprimatur on a group of great men and admits them to the sacred brotherhood of the sons of Franklin."

The six on whom this distinction was so conferred are:

William Charles Lawson Eglin, Sc.D., Electrical Engineer, Vice-President and Chief Engineer of the Philadelphia Electric Company, notable as a designer and builder of electric power plants; President of the Franklin Institute.

William Henry Bragg, K.B.E., D.Sc., F.R.S., Head of the Royal Institution of Great Britain, formerly Quain Professor of Physics at the University of London, Professor of Physics at Adelaide University, Cavendish Professor at Leeds University, co-recipient of the Nobel prize in 1915, recipient of many medals for scientific achievements and author of many articles and papers, particularly on X-rays and crystal structures.

Charles Algernon Parsons, K.C.B., LL.D., D.Sc., F.R.S., Chairman of the Parsons Marine Steam Turbine Co., Ltd., and other important industrial concerns. Famous throughout the

world as an engineer, especially for his work in developing the steam turbine.

Charles Fabry, Professor of Physics at the University of Paris, one of the world's greatest authorities on spectroscopy. Developer of important results in the construction and use of the parallel plate interferometer for the precise measurement of wave lengths of light.

Pieter Zeeman, Ph.D., Sc.D., Rector Magnificus, Professor of Physics and Director of the Laboratory of Physics at the University of Amsterdam, recipient of the Nobel prize in 1902 and discoverer and demonstrator of the effect of magnetic fields on spectrum lines. Distinguished in the field of magneto-optics.

Edwin Wilbur Rice, Jr., Sc.D., Dr.Eng. Engineer. Educated at the Central High School, Philadelphia; former President of the General Electric Co., Honorary Chairman of the Board; Chevalier Legion of Honor, Order of the Rising Sun, Third Class, Japan.

BANQUET

The celebration was closed by a banquet attended by members and guests, at the Bellevue-Stratford, with President Eglin as toastmaster.

Instead of having the usual type of after-dinner speeches, delegates were called on in the order of the seniority of the institutions they represented. This gave precedence to Professor Fabry, the University of Paris being the oldest establishment present in his person. Cambridge University and the Royal Society of England came next with Sir Ernest Rutherford as spokesman, then Professor Pieter Zeeman from the Royal Academy of Amsterdam Professor Haber from many German learned societies and universities, and Mr. Olaf Lamm, Consul-General of Sweden at New York for the Swedish Royal Academy and Universities. There followed a large number of representatives of foreign and American institutions, who advanced, each presenting an engrossed minute of greeting, concluding with President Penniman, who responded for Philadelphia, and he, too, presented a beautiful scroll from the University of Pennsylvania. This brought the official ceremonies to a close. Informal acknowledgments of the hospitality of the Institute were made by Sir Charles Parsons of Newcastle-on-Tyne and Lady Parsons, Sir William and Lady Bragg, and other guests.

The managers and officers of the Franklin Institute feel that it has been abundantly worth while to bring together so many men of eminence in scientific scholarship and achievement for better acquaintance, and to induce them to deliver in person to their colleagues their notable contributions to the advancement of human knowledge. The papers read at the various sessions will be printed in full. They form a memorable record, not only of historical value, but also to the diligent reader they are pregnant with suggestion for greater and more extended research. Franklin Institute pays its hearty tribute to the speakers who entered so warmly into the spirit of the occasion which formed a landmark in its hundred years' tradition of encouraging Advancement in Science, and in establishing science in the everyday practices of human life.

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